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Integration within the project coalition; An analysis of the structural barriers to implementing Building Information Modelling technologies

By

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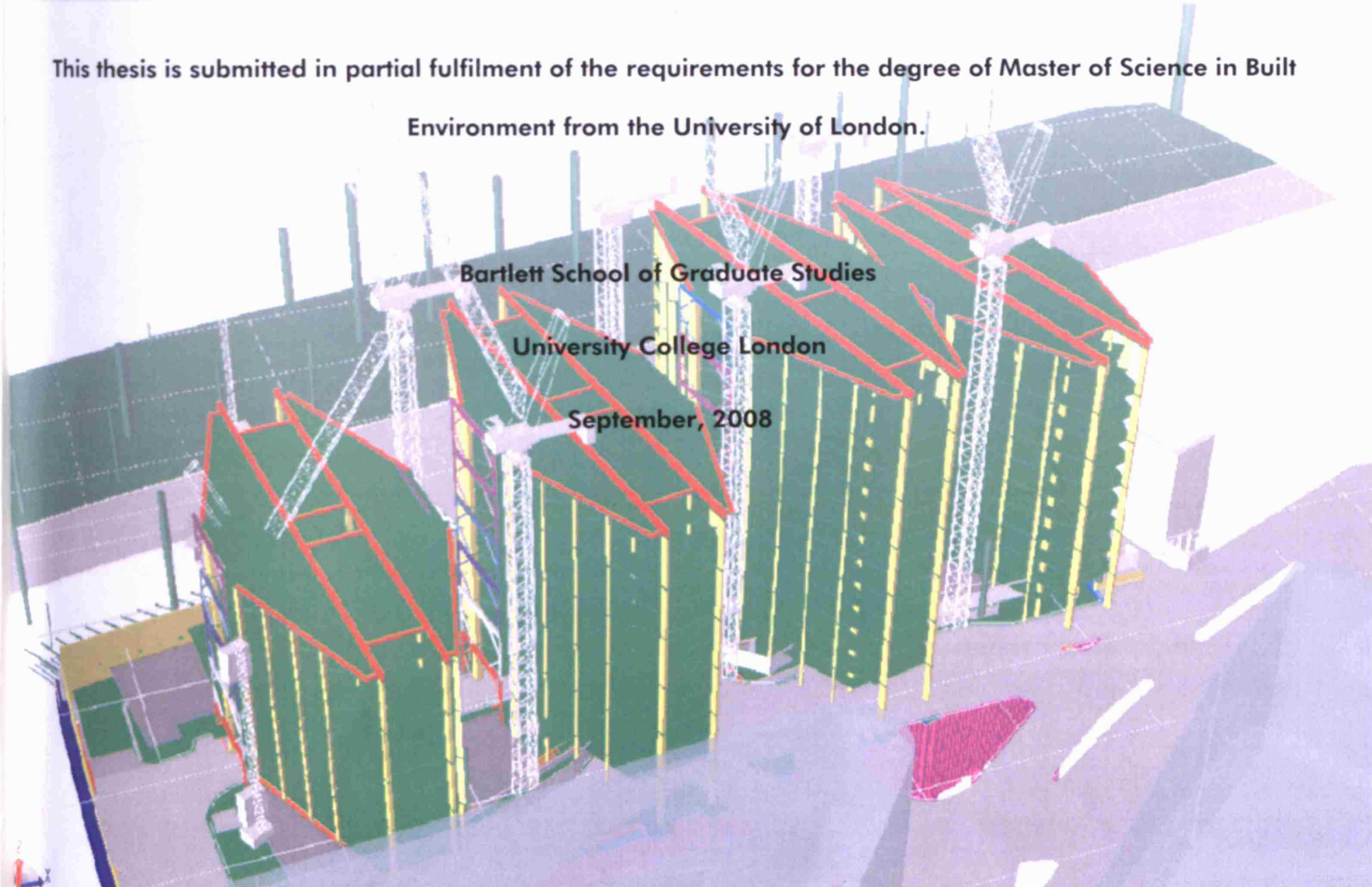

"Integration should not be left to chance because the chances are it will not happen"

Charles Handy

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Abstract

Building Information Modelling technologies are increasing in their sophistication and value to project management practice. Main contracting organisations have been slow to implement the technologies on a large scale despite calls from industry commentators to do so. There is a wealth of research available discussing the benefits of 'BIM' technologies. However, there has been little research regarding the structural barriers to implementation the technologies on live projects.

This report seeks to understand the structural reasons why Building Information Modelling systems have not yet been prolifically implemented by main contractors despite the availability of the technology. This report focuses upon procurement as a main factor regarding integration/differentiation within the project coalition and it is argued that this is a primary structural barrier to implementing integrated information systems such as BIM.

The research gathers data from 3 live projects where BIM systems have been implemented and draws conclusions regarding the relative successes and failures within the context of the project environment (procurement routes and culture etc.)

Key Words;

Integration/Differentiation, Building Information Modelling, Information Management, Procurement, Systems Thinking, Supply Chain Management,

Word Count:

1098 (excluding figures, references and appendices)

List of Acronyms

CAD – Computer Aided Design

BIM – Building Information Modelling

BDB – Building Down Barriers

IM – Information Management

ICT – Information and Communications Technology

PMIS – Project Management Information Systems

SCM – Supply Chain Management

PFI – Private Finance Initiative

Chapter 1: Introduction

A central focus of industry improvement literature has been how we can transform the diverse and separate processes of design and production procurement into an integrated process (Cartlidge, 2004). To paraphrase the Modernising Construction Report;

"The entire supply chain ...must be integrated....to improve buildability and drive waste out of processes." (NAO, 2001:4)

The most recent manifestation of this problem is evident in the discussion surrounding inter-firm collaboration (Barlow, 1997). 21st Century project management approaches focus upon adopting less adversarial methods by redefining relationships between all parties involved in the procurement and supply of built assets, creating value through long term relationships and collaborative methods (Latham, 1994; Egan, 1998). Research has focused upon how construction can take best practice from other industries, most notably automotive manufacturing and aerospace, to better manage and deliver projects.

Egan (1998) recommended that contracting organisations implement 3D technologies for buildability analysis and process efficiencies. 3D technologies in particular are widespread in the aforementioned industries and there are a wealth of products on the market claiming to aid integration and collaboration. However, implementing 3D and related technologies (commonly termed Building Information Modelling, or BIM) on live projects has been found to be challenging and no guidelines currently exist on how to utilise these tools in a multi disciplinary, multi-organisational environment (Staub-French and Khanzode, 2007). This report does not seek to provide a model for implementing such systems. This report is concerned with understanding what a suitable project environment for BIM practice may look like by exploring issues such as integration, procurement routes and culture, from a main contractor's perspective. The research will analyse 3 major UK projects which have attempted BIM implementation at project coalition level.

Chapter 2 provides the context for this research by exploring the new technological opportunities available (BIM), and discusses their relevance to project management. Chapter 3 furthers this discussion by moving on to analyse procurement routes, which are viewed as a primary structural barrier to introducing new information systems. Chapter 4 draws together these views and explores 21st Century project strategies to create a framework for understanding the best possible environment for implementing integrated BIM systems. Chapter 5 provides an overview of the research methodology used for gathering primary data and Chapter 6 discusses in detail at the findings from the field. Chapter 7 presents the final conclusions and makes recommendations for further areas of research.

Chapter 2: Research Context

This chapter seeks to explore the relationship between emerging BIM technologies and the project management function and discusses various reasons why the application of the technology has been difficult within a contracting environment.

2.1 New Technological Opportunities

The Modernising Construction report states;

"There is considerable potential to achieve efficiency improvements…by making much greater use of IT to assist in the design of buildings and streamlining the management of the construction process." (NAO, 2001:9)

There have been calls for contractor's (as primary production coordinators) to implement 3D technologies (Egan, 1998) to aid the project process. Whilst initially devised as tools for design creation, 3D modelling is used in other industries (automotive manufacturing, aerospace etc.) to develop design in an integrated manner and drive quality, management and production processes. 3D technologies are seen as a technological fix to many of the contractors' problems, most notably 'constructability' issues and communication with stakeholders.

There have been many prominent projects utilising aspects of this technology, Heathrow Terminal 5 for example (http://www.navisworks.com/index.php?q=solutions/casestudies/baa, accessed 21/06/2008), and many firms do make use of 3D in design. However, software producers are moving on from design generation to offer systems which integrate 3D design information with other project information sets; such software suites can be compared to Winch's description of a project management information system, or PMIS (Winch, 2002). The most common term for this group of interrelated technologies is Building Information Modelling (BIM) and this shall be used henceforth.

BIM is an emerging set of technologies and processes whose aim is to provide more accurate and timely information about a built asset in an integrated digital environment. Graphisoft (a BIM solutions provider) offers this definition of Building Information Modelling;

"A BIM is a computer model database of building design information, which may also contain information about the buildings construction, management, operations and maintenance." (Graphisoft, cited in Lee at al, 2005:17)

The Associated General Contractors of America goes further, defining a BIM as;

"The process of generating and managing computerized, multi–dimensional models linked to databases that house the design specifications, schedules and other documents related to a construction project. BIM provides all parties involved on a project with shared, up–to–date project data, subsequently allowing for a richer design process, increased budget control through predictions about the project's construction process and fewer surprises with respect to potential design and scheduling conflicts."

(http://www.agc.org/cs/news_media/press_room/press_release?pressrelease.id=192, accessed 07/07/2008)

The scope of BIM technologies is presently large due to their emergent nature and the diverse range of tasks within the construction project. Commercially available BIM technologies can be mapped to the main areas of the project lifecycle, as shown in Table 2.0 (albeit no single solution can be applied to all activities at present);

Project Lifecycle Phase	Application
Feasibility and Briefing	- 3D Spatial Models - 4D Planning - Marketing (Visualisations) - 5D Costing - Virtual Reality Visualisation for client briefing (Barret and Stanley, 1999) - Right to light studies
Design	- 2D and 3D Design Production - Design Coordination (Single Model Environments) - Clash Detection/Buildability (Egan, 1998) - Finite Element Analysis - Optioneering - Immersive Virtual Reality
Delivery	- Design Management - Measurement - 5D Costing, EVA and Cash Flow - 4D Planning and progress mark up - Offsite manufacture (CAM) - Onsite briefing through visualisation - Setting Out - Database storage of specifications etc
Operation and Maintenance	Outside of the scope of this report

Table 2.0; Applicability of BIM to project phases (adapted from Aouad et al, 2000)

This paper does not seek to create a common definition or technological model for all projects; available technologies will be alluded to where relevant and a high level overview of BIM is given in Appendix A. This report is primarily concerned with the benefits brought to project management including improved information flows, better quality information, collaborative environments and improved reporting. The applicability of information management tools to the project management process is discussed in the following section.

2.2 BIM and Construction Project Management

Information management is a key concern for successful project delivery;

> "All organisations are in essence information processing systems…information flows are at the heart of the business processes of all organisations," (Winch, 2002:6)

The project process involves the reduction of uncertainly over time (Winch, 2002). Uncertainty is reduced by the production and utilisation of good quality information. The rule of Garbage In/Garbage Out is particularly pertinent in construction projects; poor, untimely information inhibits decision making and does nothing to reduce uncertainty (Winch, 2002).

In order to increase the probability of information being processed in a timely and appropriate manner, structured information management systems are required; BIM is an information management paradigm. Winch (2002) presents the concept of Project Management Information System; systems designed to support the project management function, shown in figure 2.0.

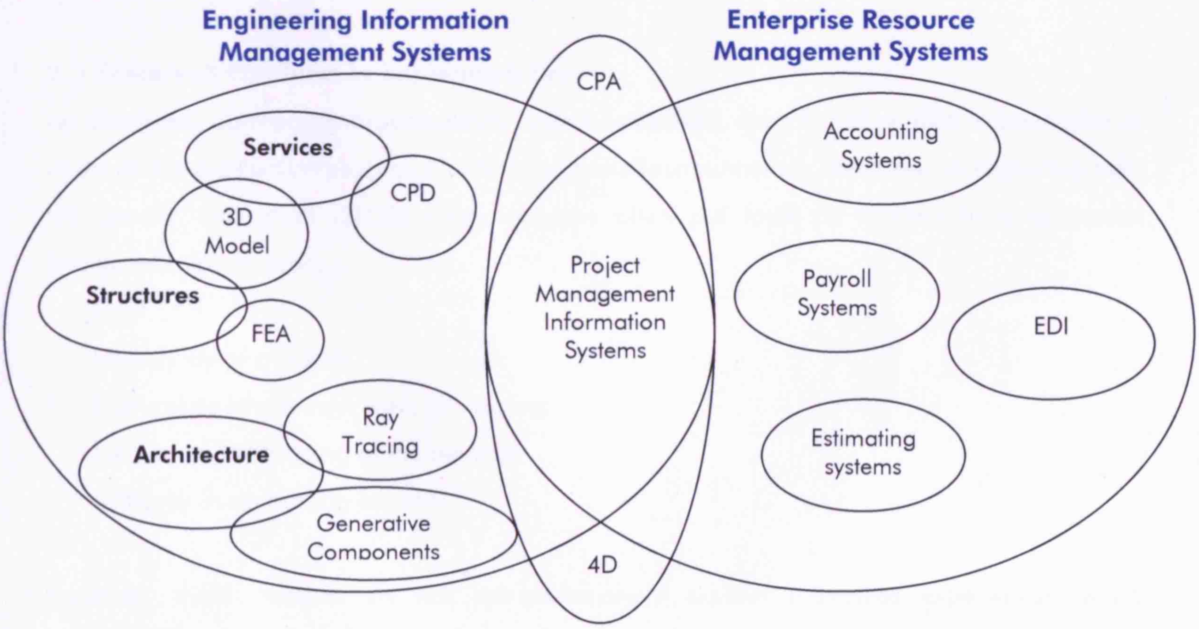


Fig 2.0: Generic PMIS representation (adapted from Winch, 2002)

The flow and re-use of data between resource bases is a key issue in project management (Winch, 2002). If data can be harvested from one resource base and be automatically utilised in another's, the likelihood of error in data interpretation is reduced and the process of information production and use in disciplines is expedited. This is particularly useful in design driven activities as design is an iterative process (Boyle, 2003). Design changes result in the need to generate further information outputs for other disciplines.

Some BIM technologies assist in this reciprocal process; by intimately linking design systems to estimating and planning systems repetitive re-calculation can be reduced (please see Appendix A for further background information). BIM essentially seeks to integrate data sets from various resource bases to create an improved information flow to aid project management throughout the project lifecycle. BIM can create linkages between design functions and enterprise functions, between design firms and production firms. This 'virtual integration' would seem to go someway to satisfy requests made in the Modernising Construction report, such as;

> "Better integration of the various stages in the construction process – design, planning, construction and completion to remove waste and efficiency," (NAO, 2001:5)

As discussed previously, firms responsible for design are using constituent parts of BIM systems (3D CAD etc); contractors are beginning to use 3D systems for buildability and clash detection. However, despite the integrative ability of commercially available tools, contractors are embracing the technology at a slow pace. This report seeks to understand some of the structural issues surrounding this seeming lack of take up.

2.3 Observed Problems in Implementation

As discussed, contracting organisations have been called upon to utilise BIM technologies to improve the production process. Contracting firms face numerous difficulties in exploiting their full benefit. Lee et al (2005) offers reasons often put forth as barriers to a successful implementation include;

- Cost
- Immaturity of products
- Cultural apathy to new ways of working
- Lack of understanding of the benefits
- Difficulty in measuring benefits

However, these reasons do not comprehensively explain difficulties experienced when implementing BIM. This is evident as BIM has not been implemented on a wide scale by any main contracting organisation and few large projects have demonstrated real value through by using BIM (Lee et al, 2005). The following sections offer further factors which may hamper project level BIM implementation;

2.3.1 Information

The following difficulties have been observed on various projects by the writer and have frustrated implementation of BIM systems and work practices;

- Information not available at the required time (Walker, 2002)
- Information lacks detail (Walker, 2002)
- Information is not shared amongst appropriate project actors (Walker, 2002)
- Information not in an appropriate format (Winch, 2002)

Design organisations may utilise BIM internally but not in a manner that is useful to the contractor downstream; much of the time it is unknown during design stages whom the contractor will be, thus the designer will not know that the contractor can accommodate such information, losing the integrative capability of the technology. Design information may be re-created by an enthusiastic contractor to complete buildability studies, as requested by Egan (1998). Re-production of information introduces re-work into the project and can also add risk; transposition errors create risks of misinterpretation, hampering good decision making. This is compounded when we consider 5D models where design elements directly affect estimating and planning output.

2.3.2 Culture, Power and Influence

The industry is traditionally a poor adopter of I.T. (NAO, 2001), and has a reluctance to invest in Research and Development (Egan, 1998). Also;

- 3D Designing is neither a contractual obligation or prolifically sought by clients
- There is a lack of trust in transferring live 3D data between firms as uncontrolled design information may present a commercial risk
- Implementation of new systems once on site is difficult; people are busy doing their day job
- Contractors may have difficulty influencing other coalition firms to adopt tools, protocols and practice for the production of design information
- Contractors must work across several supply chains which have different demands for tools, protocols and practice

2.3.3 Technological Barriers

This report is essentially an investigation into the organisational barriers to implementing BIM; technological problems are deemed to be outside of the scope of this report. However, one key concept will be raised briefly; namely interoperability (Winch, 2002). Commercially available BIM software's use different data formats which are not always compatible, preventing the exchange and use of data between resource bases; thus the integrative capability is lost.

2.4 Summary

As Winch (2002) states, that the aim of a PMIS is to ensure that accurate and current information is available to the relevant people, in the correct format and at the right time. Therefore, an information management strategy is a key consideration in the implementation of a BIM system.

Winch states that the generation of project information is primarily the responsibility of designers, since design information comprises a large percentage of project information. However, the development and use of this information is mainly by those responsible for the production function (Winch, 2002). Subcontractors and suppliers can also have design and responsibility (Latham, 1994), further complicating the network of information flows.

Traditional project implementation strategies often sever the design and production functions. Therefore it follows that information management within the project environment is subject to the effects of fragmentation. Fragmentation in the project coalition is governed by the tendering arrangement chosen for delivery (Walker, 2002). The procurement of a contractor has a profound impact upon the interfaces between the design and production functions; early appointment gives the contractor an opportunity for input into the design, later appointment reduces this opportunity. Several procurement routes seek to allocate design specifically to the contractor (along with associated risks), while others seek to limit this input.

The use of BIM technologies and practice helps to integrate functions within the project, to leverage information and aid project delivery. Therefore it can be surmised that a procurement route which fragments the interfaces between designers and production coordinators may create a hostile environment for BIM and the issues discussed in the previous sections would be perpetuated. Also, questions of power and influence arise as a central, integrated information management approach would require a powerful central actor advocating and enforcing standards protocols.

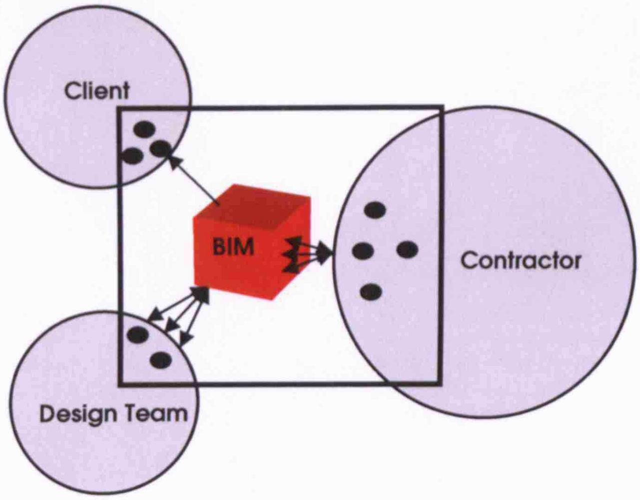


Fig 2.1; BIM interface between project firms (adapted from Pryke and Smyth, 2006)

Section 3 will look at the notional levels of integration for UK procurement processes in order to understand what is likely to offer the least hostile environment for implementing BIM.

Chapter 3: Procurement Routes - levels of integration

This chapter seeks to further discussion of the structural barriers to implementing inter-organisational information management tools such as BIM and draw out the key elements which will be taken forward to form a theoretical framework for implementing BIM technologies more successfully.

It has been asserted that the information issues discussed stem from a lack of integrated information management as a result of 'silo' working. Further investigation is required in order to develop a framework in which we can understand and test the conditions most likely to create successful environment for implementing BIM. Integration can be described as the quality of collaboration between departments required to achieve unity of effort by the environment (Emmit, 2007). The following sections will briefly look at the notional levels of integration within UK procurement routes.

3.1 Traditional

Competitive lump sum tendering relies on design being completed by the design team up front. The contractor shares no responsibility for design (which is completed in advance of contractor involvement), therefore his route contains a poor degree of integration between design and production teams (Walker 2002).

This route is also recognized as being inherently adversarial in practice; lines of communication are often difficult (Franks, 1998). Walker states that during the construction phase difficulties persist in trying to integrate the design and construction teams as psychological factors are present; contractors may not believe in the design and designers may not believe in the contractor's motives; adversarial relationships persist, hampering collaboration (Walker, 2002).

3.2 Management Routes

Management Contracting integrates the contractor into the design team as a fellow consultant early on; thus allowing parallel working (Franks, 1998). Specialist subcontractors are engaged to provide detail design early on, lowering design risk and further integrating second tier suppliers and subcontractors into the design phase. This level of integration would seem suitable for attempting the implementation of new information management approaches. However, as the contractor is not the primary agent for delivery there may be no impetus for the design team or supply chain to cooperate; there is no buyer-seller relationship (Cox and Ireland, 2007). Also, pre-existing allegiances and attitudes may stifle the integration of a main contractor into the design team, making implementation difficult (Walker, 2002).

Whilst similar in structure to Management Contracting, Construction Management essentially removes the main contractor; the client, or client's representative, coordinates and manages trade contractors thus assuming their responsibilities (Walker, 2002). Therefore, further analysis shall not be undertaken as this paper focuses on implementing BIM main contractor's perspective.

3.3 Design and Build

Design and Build places responsibility for both design and construction with the main contractor. There are many shades of Design and Build, each with its own level of integration (Walker, 2002). A novated route provides the lowest level of integration as it requires consultant designers to design to a predetermined level of detail; the design is then taken on by the contractor to detail in parallel with developing the construction methodology (Franks, 1998).

Both the contractor and consultants may not feel that novation allows them to further the project in a way they feel appropriate (Franks, 1998). Therefore adversarial behaviours may still persist and integration will be fraught with behavioural difficulties.

3.4 Private Finance Initiative

PFI is a government procurement route which is essentially a Design and Build style framework (Franks, 1998), the key difference being that the route may also include financing and operation of the facility as part of the contract (Cartlidge, 2004). Involvement is generally earlier, adding value in the definition of objectives and helps create a more appropriate strategic response to project implementation. Also, the earlier involvement helps form relationships with consultants earlier, thus aiding integration.

However, there is often an Architect appointed by the local authority client early on; an element of novation may be present which potentially brings with it similar integration issues as design and build.

3.5 Partnering

As defined by the Latham report, partnering is where;

> "Parties agree to work together in a relationship of trust, to achieve specific primary objectives by maximising the effectiveness of each participant's resources and expertise." (Latham, 1994:62)

Partnering redefines the relationships between clients and supply side firms; collaboration is required to deliver shared objectives for mutual benefit; partnering can be viewed as a set of collaborative process (Barlow, 1997). Partnering is in effect an approach which is aimed at providing integration between all actors. The proposed benefits and problems associated are outlined in table 3.0;

Benefits	**Problems**
– Reduced costs	– More time may be spent communicating due to multiple interfaces
– Shortened delivery times	– Higher management overheads
– Enhanced quality	– Uncertain pay off
– Better working atmosphere	– Uneven balance of power between firms
– Fewer disputes due to the context of relationships	– Organisation roles can be more ambiguous
– Opportunities for technical and process innovation	– Mistaken belief that basic formalities and structures go without being replaced by an alternative
– Organisational Learning	– Cultural change takes time
	– A standard model does not work for all projects

Table 3.0; Partnering; benefits and problems (summarised from Barlow et al, 1997)

Barlow et al (1997) offers several success factors required to ensure successful partnering;

- Long term commitment and relationship
- Mutual understanding
- Openness and flexibility of communication
- Trust and teamwork
- Empowered personnel
- Commitment from the top

An interesting aspect of partnering within the context of this study is the focus upon open and flexible communications. Barlow observes that one feature of partnering is the breakdown of formal communications hierarchies for the simplification of information flows (Barlow, 1997), something which would require integration at both firm and actor level.

A partnering relationship can be described as a strategic alliance between firms, which provides opportunities for innovation, learning and importantly, knowledge transfer (Barlow, 1997). The ability within a partnering framework to structure more appropriate communication and information sharing methods, combined with the opportunity for knowledge exchange, could be said to provide an appropriate environment for implementing an integrated BIM strategy. However, partnering in itself may not be a sufficient framework for procuring a project as in its simplest form it may require little more than cooperation from project actors (Pryke, 2005).

Therefore, a more prescriptive management framework is required which employs the collaborationist philosophy of partnering. Supply Chain Management is an inter-firm management paradigm which is aimed providing this and will be discussed in Section 4.

3.6 Tendering Process

The two-stage tendering route is designed to allow the contractor some involvement in the design stage but maintains competition in contractor selection (Walker, 2002). This is done by an initial competitive period (first stage) followed by commercial negotiations alongside the detailing of design. This approach does allow further integration of design and contractor teams but as the contractors involvement is not from the beginning the full benefits of integration are not realised (Walker, 2002).

The application of a partnering arrangement should seek to replace competitive tendering process as the client and the contractor are brought together through a relationship focused upon mutual objectives (Egan, 1998). Commercial negotiations are still present but in theory are more open, potentially removing the adversarial behaviour which hampers collaboration and thus, integration.

3.7 Summary

It has been proposed that the barriers to BIM implementation discussed are a direct result of fragmentation within the project coalition. Therefore, it can be concluded that a primary concern when attempting to implement BIM technologies into the contracting organisation is the procurement path chosen, since this is the overriding factor governing fragmentation/integration, the project process and the division of labour amongst the project coalition. Procurement governs when a contractor is appointed to the project and the level of influence the contractor has in shaping the project delivery strategy, including information management.

The traditional approaches to project procurement have elements which would allow a degree of BIM implementation since they allow some degree of integration between design and construction teams; this is in evidence in the industry at present as a large amount of companies, in both design and production, are implementing BIM tools within their internal processes. However, no single route seems to provide the optimum conditions for implementation which would provide a complete project level information system; design and build does not always yield collaboration of the level required and novation removes the power of appointment. Management contracting does not incentivise the contractor to implement improvement methods nor does it provide the contractor with authority over consultants work; adversarial behaviours can still be seen between designers and contractors. None of the routes allow the contractor to be introduced into the process before consultant designers begin work (with the exception of the PFI/PPP variant of design and build), therefore project information will be created before a contractor is appointed.

As previously stated fragmentation is governed by tendering arrangements (Walker, 2002). It is worth noting that fragmentation also includes the division of work into separate contracts. Partnering approaches seek to change this by focusing on relationships rather than contracts. PFI also seeks to bring together the usually separate contracts for Design, Build, Finance and Operate under one contract.

Furthermore, it is widely accepted that traditional procurement practices perpetuate adversarial behaviours between project actors, thus creating negative impacts on product development and therefore, project outcomes (Emmit, 2007). Implementing a project management information system requires buy-in and cooperation of all actors contributing information. Collaboration and cooperation is unlikely to occur on traditionally procured projects as fragmentation is structural, but also cultural.

The proposition that procurement is the main factor when implementing BIM technologies shall be carried forward in to the next section. More modern project management strategies will be analysed and a theoretical framework developed.

Chapter 4: Theoretical Framework

This chapter will further discuss factors such as early involvement, integration, strategic involvement and culture, which where outlined in the previous section and develop a theoretical framework to understand what may be a more suitable project environment for the implementation of BIM.

As discussed, traditional procurement approaches usually only allow for contractor appointment long after design has been begun, creating issues such as;

- Difficulties integrating the project team for reasons such as conflicting commercial interests and cultural divides between professions (Walker, 2002), thus perpetuating adversarial relationships
- Contractors lacking the power to influence project coalitions member firms internal processes
- Lack of strategic input from the contractor in the project execution planning

These factors contribute to the reduced potential for a contractor to scope and implement an information management approach which would serve to further integrate design and production and support information sharing. Driven by improvement initiatives suggested by industry commentators, new project approaches have emerged in recent years. To paraphrase Pryke;

> "The industry has made significant efforts to introduce less adversarial approaches to construction and to reconfigure traditional relationships that existed between the actors within the project team" (Pryke, 2004:5)

These '21st Century' approaches focus upon re-organising the project organisation, tailoring it more specifically to client objectives to increase the likelihood of successful. It is argued that this cannot be achieved without collaboration, integration and cultural change. Section 3.5 introduced partnering as a redefinition of the relationships within the coalition. The following section takes this concept and attempts to understand a more applied framework for integrated project management, within which a structured information management approach, such as BIM, could flourish.

4.1 Supply Chain Management

The application of SCM methods within construction is a recent fashion which is closely related to the strategic partnering approach discussed previously. It has been asserted that partnering is a prerequisite to SCM within construction (Pryke, 2005). SCM can be defined as;

"...the management of upstream and downstream relationships with suppliers, distributors and customers to achieve greater customer value at less cost" (Christopher, cited in Pryke, 2005:3)

The main contractor acts as the production coordinator within the construction project and is responsible for integrating and overseeing packages of work, including component assembly and site crafted work (trades), to create the built asset (please see figure 4.0). SCM can be described as an approach which seeks to fully integrate an inter-connected network of organisations to deliver a project (Venkataraman, 2004).

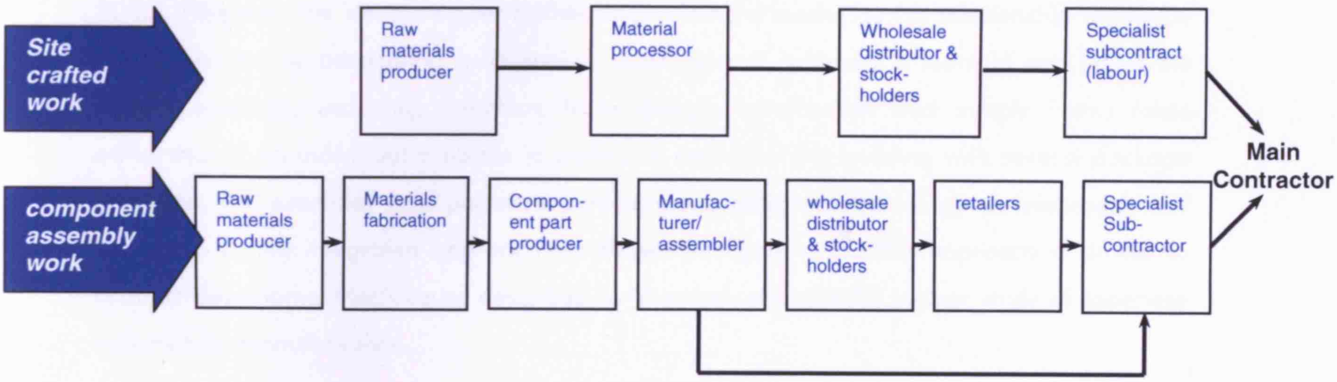


Fig 4.0; Supply chain model (adapted from Pryke, 2009; forthcoming, after Harland 1996)

Cox et al note that SCM requires proactive supplier development work, beyond the first tier of suppliers (Cox and Ireland, 2006). This is relevant as there may be a degree of business process re-engineering (or re-alignment) required between firms required to allow a project management system to integrate with the supply chain processes and therefore allow data to be passed between tiers. Also, some organisations will be more familiar with the technology than others.

It could be argued (especially given the long term commitment requirements of partnering relationships) that forming a standing supply chain which is able to integrate at business process level through BIM technologies would offer clients a differentiated service proposition; something which could be leveraged across projects. However, this requires SCM to be initiated by the main contractor, not through the client, which is the approach prevalent in the majority of the literature. Pryke notes that;

"In order to successfully manage a supply chain a central actor is required with the authority to deal with all other actors within the supply chain." (Pryke, 2005:14)

Main contractors are ideally placed to fulfil this function as it is in effect what Winch (1998) describes as their traditional 'systems integrator' role. Winch (1998) states that a complex systems industry such as a construction requires systems integrators; those who provide the interface between the infrastructure (the supply chain for example) and the superstructure (clients, regulatory bodies etc). The Prime Contracting approach offered by the Building Down Barriers report effectively offers an applied model for SCM; a key aspect is that a single agent leads the integrated, long term supply chain (Holti et al, 2000).

Like partnering, Prime Contracting requires upon a high degree of integration (Holti et al, 2000). However, the literature goes further by providing a model for this relationship within the project context by advocating a 'clustering' arrangement, whereby a team (a sub set of the project coalition, including members from design, construction and supply firms) takes ownership of an individual problem (a particular section of the building with several package interfaces for example) and performs simultaneous design/methodology development and pricing in a fully integrated approach, as shown in Figure 4.1. This approach is similar to product development techniques described by Womack et al (1990) in their study of Japanese automobile manufacturers.

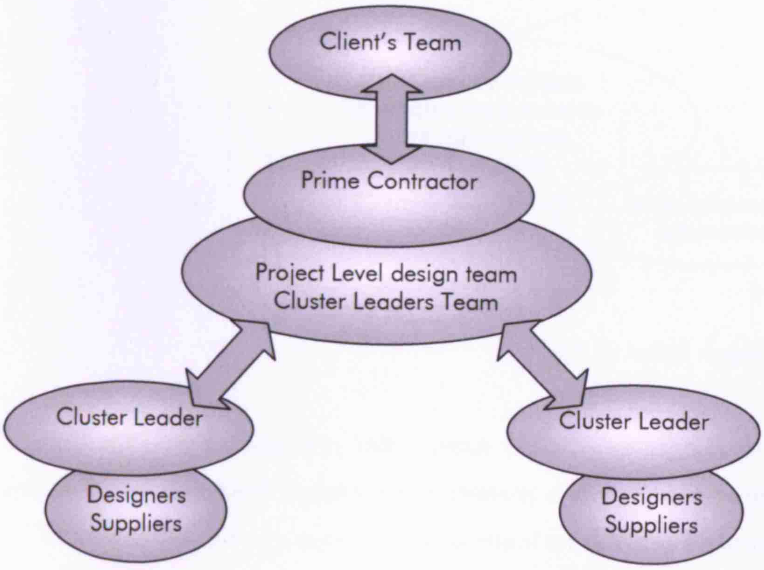


Fig 4.1; Clustering model of project organisation (Holti et al, 2000)

Clustering is of particular interest when assessing the implementation of BIM because of the high level of integration required. Also, the cluster could be supported by a BIM environment which allows design development, automated pricing and programming (a 5D system; please see Appendix A for a concept model).

4.2 21st Century Project Strategies Summary

Analysis has highlighted several key themes which, in theory, would satisfy some of the requirements for project wide BIM implementation;

- Early involvement of the main contractor
- Further integration of design and construction
- Partnering style environments with a focus on collaboration and cooperation in place of adversarial behaviour
- Supply Chain development
- Power and centrality within the supply chain

Thus far the analysis of procurement routes and 21st Century project strategies have led to the initial framework below, shown in diagrammatic form;

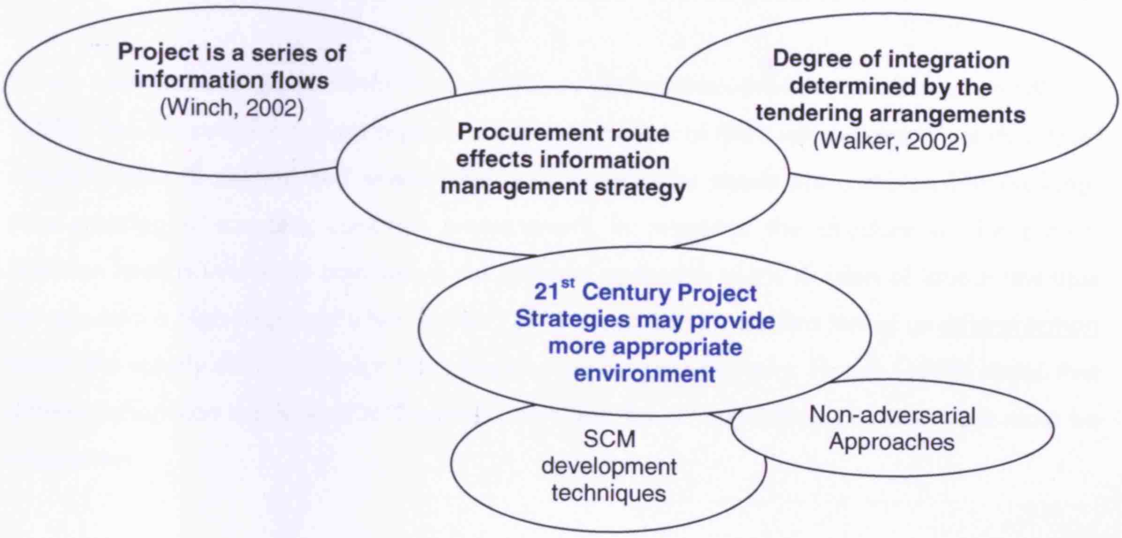


Fig 4.2: Initial research framework

The following section will re-introduce the information processing aspects of the research problem and explore further structural issues such as strategy and culture in order to formulate a final theoretical framework for a more suitable environment for BIM implementation.

4.3 Further Analysis and Discussion

It has been argued that as a reaction to the problems attributed to traditional procurement, newer approaches to project management have become focused on re-organising the project coalition structure, thus changing the organisational context, shifting the emphasis of power and establishing new cultural values.

Re-organising the project coalition and Winch's (2002) suggestion for management of the organisational context can be related to a systems thinking perspective. As Walker states;

"The greatest benefit of the application of systems thinking to construction is the structuring of organisations in such as way as to achieve the client's objectives" (Walker, 2002:61)

It is argued that a soft systems approach to delivering a project is essential, particularly in the early stages where the project may lack definition or clear objectives, because this approach views the project and its constituent parts within the context of its environment and not as a set of separate, independent issues (Checkland and Scholes, 1990). This is noted within Winch's information processing approach;

"Where a number of decision makers act independently of each other with incomplete information about the implications of their decisions on those dependent on them, then perverse dynamics can be created" (Winch, 2002:427).

Winch asserts that organisational structure directs and enables the flow of information (Winch, 2002). The construction project organisation is a coalition of firms which aims to satisfy a brief which is often ill defined and where client and stakeholder needs are complex and evolving; thus creating a complex, dynamic environment. In response the structure of the project coalition itself is inherently complex; a risk adverse approach to the division of labour has thus far required a high degree of what Walker (2002) describes (in systems terms) as <u>differentiation</u> within the supply chain; different firms responsible for specific tasks. Handy (1999) states that differentiation can easily lead to fragmentation and for differentiation to work there must be integration.

In addition, there is the inherent danger that a task will be performed without due consideration for other tasks dependent upon its outcome; traditional approaches to project management can be dominated by this fragmentation and differentiation resulting in the management of tasks carried out in isolation using sequential information flows; a 'silo' approach.

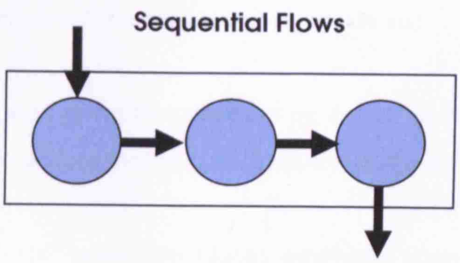


Fig 4.3; Sequential information flows (Winch, 2002)

The information processing paradigm places importance upon how we can manage the project process through managing the organisational context i.e. manipulating the structure (Winch, 2002). Since procurement routes shape the project organisation, procurement strategy has a profound influence upon the project information flows. New approaches to project management advocate a collaborative effort between interconnected firms within the project coalition, which in systems terms suggests an inherent level of feedback supporting collaboration; a reciprocal approach to task management.

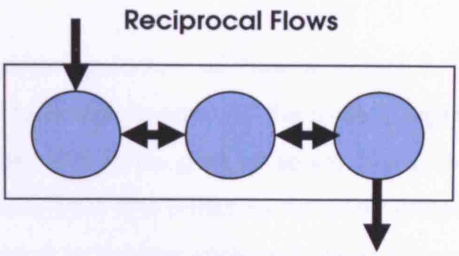


Fig 4.4; Reciprocal information flows (Winch, 2002)

This idea is developed, and its implementation observed, by Holti et al (2000); the clustering approach, as discussed in section 4.1, could not be achieved without reciprocal, even iterative (where problems are difficult to define as up or downstream, such as in design) information flows and open interfaces between actors within the supply chain.

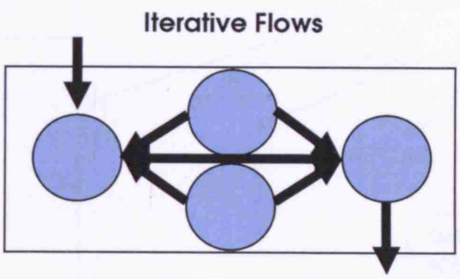


Fig 4.5; Iterative information flows (Winch, 2002)

Applying a systems type approach to project structuring, such as Winch's Information Processing approach (Winch, 2002), requires a strategic view of a projects' management. Morris (1994) argues that a strategic approach to the management of projects, with a focus on organising the project at the front end, is a distinct paradigm shift from traditional project management. Morris defines simplistic project management as;

"The process of integrating everything that needs to be done…as the project evolves through its lifecycle…in order to ensure that its objectives are achieved". (Morris, 1994: viii)

The "management of projects" paradigm places emphasis upon defining the problem and setting the project objectives at the outset in order to design a project delivery methodology which seeks to achieve the maximum chance of success technically, commercially and socially (for all stakeholders) whilst satisfying the project objectives with efficiency and effectiveness (Morris, 1994).

There is recognition of the effects of the external environment upon the project within this paradigm. The construction project has been described as an open system, susceptible to external regulatory, economic and political influences, leading to emergent properties within the system (Walker, 2002).

Walker states that the determining factors of how a system is structured and operates to achieve its objectives are the technical demands of the project, together with the environment in which it is undertaken (Walker, 2002). He goes on to say that such analysis demands that the structure developed individually from first principles for every project (Walker, 2002). Cox and Ireland warn that focusing upon techniques such as SCM and Lean may be misguided for the same reason and that it may be more pertinent to understand appropriate tools and techniques for the particulars of the individual project (Cox and Ireland, 2006). This underlines the importance of selecting an appropriate strategy and it can be argued that this is split into two issues; strategy governing the project organisational design and strategy governing the information management approach. Figure 4.6 below describes a model for the management of projects approach; the importance of structure, behaviour and systems are key considerations.

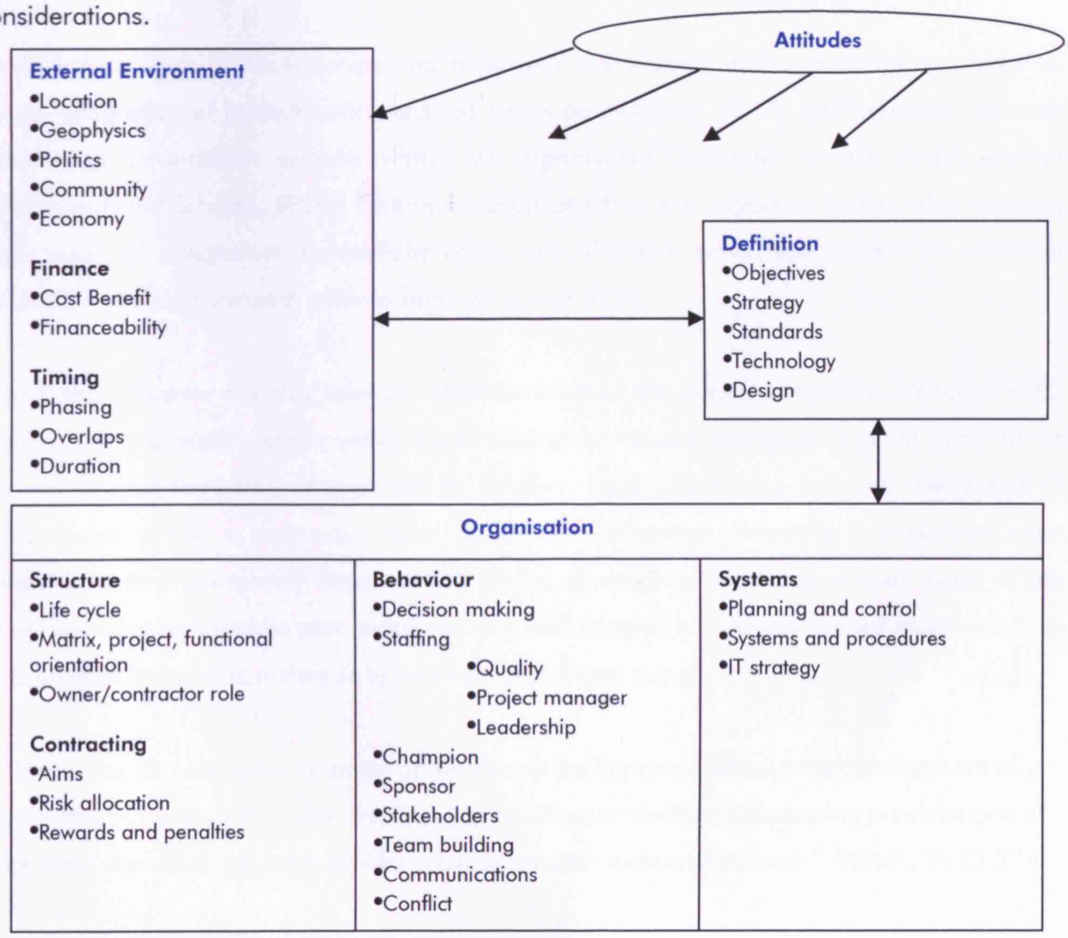


Fig 4.6; Framework showing the principle items that must be managed for success (Morris, 1994)

This paradigm also identifies behaviour as an important factor alongside structure, recognising the relevance of softer issues in project strategy.

A lack of integration can prevent the main contractor from implementing a highly structured information management approaches which leverage data between resource bases. 21st century project approaches are designed to directly remedy the issues inherent within traditional procurement approaches. However, integration of the supply chain also requires relationships between design consultants and specialists to be geared towards consistent collaboration (Holti et al, 2000). Therefore removing structural barriers is only part of the solution. It is argued that projects are inherently social (Pryke and Smyth, 2006). Therefore, strategy needs to recognise relationships, behaviours and culture. It can be argued that a soft systems approach is also useful here;

> 'The soft systems approach is...concerned with human behaviour in organisations... to advocate and to communicate become more important than applying scientific methods, searching for some elusive truth and reducing all problems to rigorous mathematics.' (Daniel, 1990:81)

Social factors such as relationships and behaviour are relevant to this study for two reasons. Firstly, integration of project actors requires social parity (Emitt, 2007). And secondly, because introducing information systems within an organisation inevitably entails social change (Checkland and Scholes, 1990). Communication and trust are important factors when seeking high levels of integration and collaboration, two elements which are evident in relational approaches to procurement, such as partnering and SCM.

Power and influence are also relevant. Main contractors are system integrators (Winch, 1998). Power over the supply chain within traditional procurement strategies is most likely to be derived through the power of appointment (Walker, 2002). Partnering increases the chance of repeat work giving a contractor more power and influence. Influence is important when considering new processes; firms outside of the contracting organisation may need strong incentives to accommodate new processes and technologies (a risk and reward situation). SCM may provide better circumstances to innovate and create buy in;

> "Incentives for innovation in construction cannot be improved without the development of a gain-sharing approach....The shift from competitive tendering to partnering provides one of the most important opportunities for moving towards such an approach" (Winch, 1998:274)

Centrality is also an important issue when considering both power and information flows, particularly design development networks, as centrality is an effective way of measuring the relative leverage of actors within a given supply chain (Pryke, 2004). However, centrality can be transient in the project network and can ultimately rest with an inappropriate actor, hampering information flows.

4.4 Discussion Summary

Most notable improvement strategies have advocated that contracting firms should be involved earlier in the project process, with a particular focus on integrating them into the design stages of a project (Latham, 1994; Egan, 1998; Holti Et al, 2000; Cain, 2003). PFI, Prime Contracting and SCM demand that the contractor should take a more long term, strategic view of service provision, and be a central force in the creation of project strategy. This is aimed at providing the opportunity to structure the project process in a way which is suitable for the specifics of the project and its production function, increasing the likelihood of success.

Prime and PFI approaches also bequeath power and influence to the contractor not evident in other forms of procurement. Walker identifies the power of appointment as crucial in the ability to influence consultants (Walker, 2002). These factors can contribute to the ability to map desired information flows for the project process ahead of design creation. Partnering and SCM techniques contribute collaborative relationships, knowledge transfer and supplier development; it is proposed that SCM relationships should be expanded to encapsulate designers also since it is they who are producing the bulk of the information within the project coalition;

> "Partnering will deliver the greatest improvements in performance where it is the basis of the long-term strategic relationships between firms on the design and construction supply-side of the industry," (Cain, 2003: 36)

4.5 Final Framework and Hypothesis

Figure 4.7 represents the final theoretical framework for this research project, showing the previous analysis in diagrammatic form. The proposed key factors effecting BIM implementation are shown within a setting of the management of projects paradigm.

It is proposed that the common threads inherent in the approaches discussed can assist in formulating a framework for understanding the application of a more integrated, structured and technologically advanced information management approach, thus facilitating the implementation of BIM technologies. It is argued that the common elements shared, which are useful in understanding the nature of factors intrinsic to construction project management, include;

- Integration/fragmentation between firms and actors
- Culture of collaboration within the supply chain

- Power and influence

The triad of approaches are shown within the backdrop of Morris's management of projects paradigm. In the case of the Information Processing approach and 21st Century project strategies, each approach seeks to re-define the project process at a strategic level and thus embed protocols, behaviours and systems more suited to the specific challenges and goals of the project. In the case of a systems perspective, this is a useful window through which to view the problem of integration and the application of information systems within the total project system; using a systems approach to solve the problem of project process also requires a strategic view. It is offered that the final element common to all paradigms is;

- A strategic view of the project process

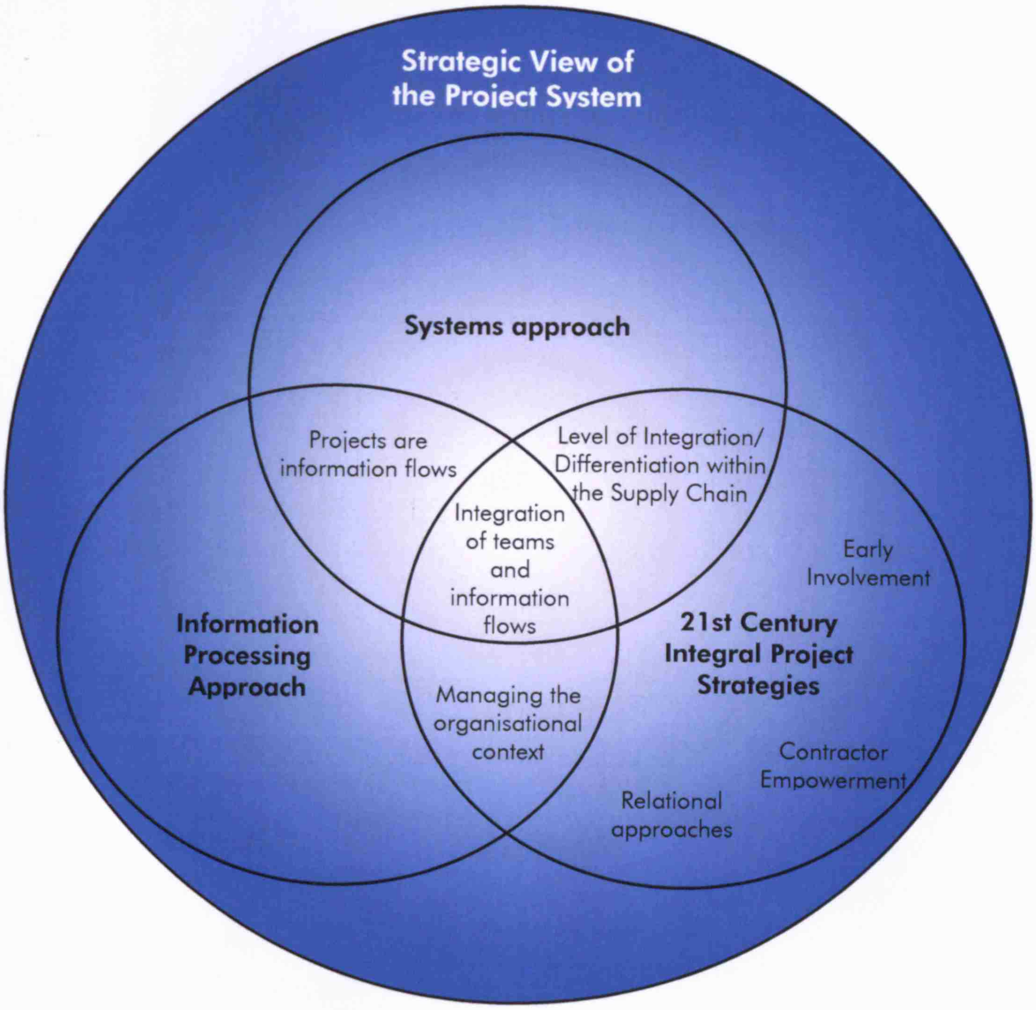


Fig 4.7; Final Theoretical Framework

Therefore the primary view of this report is that implementation of a disciplined IM strategy such as BIM will have more chance of success where the procurement strategy used to appoint the main contractor used provides;

1. Early involvement of the main contractor

2. Scope for highly integrated design and production functions
3. Strategic input for the contractor regarding the project execution strategy (including detailing an IM approach)

Secondary factors include;

4. Partnering style relationships within the project coalition leading to the application of SCM techniques such as mutual improvement and knowledge transfer
5. Sufficient resource is attributed to leadership and change
6. The contractor wielding a high degree of power with which to influence the design and supply chains.

Chapter 5: Research Methodology

5.1 Introduction

The main issues to be understood by this field research is the effect of the live project environment upon BIM implementation, in order to understand the relationship between an integrated project coalition and the success of implementing a more structured information management approach supported by technology.

In order to test the hypothesis, empirical research was carried out on live projects. The research will aim to understand the quality of BIM implementation on several projects in order to understand the potential reasons behind successes, failures and other issues experienced by the project teams. This was done by exploring individual actor's perceptions of the project environment and of the BIM implementation itself. The research specifically looked for;

- Perceptions of project cultures, in terms of collaboration and cooperation
- Perceptions of the quality and types of relationships
- Perspectives on the benefits derived from BIM within a live project environment
- Evidence of SCM techniques and strategic planning

5.2 Method of Research

The research was conducted using a qualitative method consisting of case studies of major UK projects where BIM technology has been utilised in some capacity. Quantitative research relies upon a mathematical analysis of data. The difficulty of putting key performance indicators against the use of BIM technologies (Lee et al 2005) combined with a lack of contractors making use of BIM means that quantitative research would be too restricted and not yield enough data to draw meaningful comparisons.

Semi structured interviews where conducted using a questionnaire to provide a qualitative data set which comprised of some multiple choice questions (including Likert scales) and some open ended questions allowing the respondent to articulate their own observations. It was envisaged that this method would yield the subjective opinions of actors closely engaged in the project process and who are using BIM, and expose associated points of interest particular to the actor's experience.

It should be noted that the use of Likert scales does not indicate a quantitative analysis as the sample size is too limited. Likert scales where used to assist the respondent in articulating answers, thus allowing more meaningful comparison and graphical representation.

5.3 Sampling; Contracting Organisation

Three major UK projects where studied, all from within the same contracting organisation. This organisation was selected in particular because of its history of investing in BIM (it has employed teams to implement the technologies into its businesses). This is not to say that its competitors are not involved in BIM, but to the writers knowledge there is no other organisation within the UK with the same ambition regarding BIM technology, nor the investment to match at the time of writing.

Another contributing factor to the decision to sample one contractor is that the difference between main contractors business models can be large and their approaches radically different. Therefore any comparison between approaches may be futile as project approach and processes may not correlate. Using projects from the same contracting organisation normalises some of the factors prevalent in each case and makes for more meaningful comparison.

It is worth noting that the main contractor in question has an in-house, vertically integrated supply chain including a concrete frame and mechanical and electrical sub-contractors which are employed on the sample projects. However, these businesses can and do operate with a degree of autonomy, even between regions within the same business (an important factor when considering new approaches to managing work).

5.4 Sampling; Projects

The projects sampled ranged from around £230 to £450m in value, two of which where PFI hospitals and one was a speculative residential development using a Design and Build route. All three projects contained an element of novation and all three where designed by highly acclaimed architects.

The difference in building use is not deemed important within the context of this study. Both can be modelled in a BIM environment to the same extent and in many cases similar construction methods (all concrete frames and highly serviced etc). An overview of each project can be found in appendix C.

The projects where selected because of their implementation of BIM technologies, particularly the presence of 3D (3D interfaces being the focus of research and development in the BIM market). An informal investigation was done prior to the main research within this paper to understand the contracting organisations current 'BIM enabled projects'.

The hypothesis of this paper is centred on the effects of procurement routes upon BIM implementation; more specifically the integration/fragmentation created by the procurement route within the project coalition and the power centres created.

All projects feature a contractor led design team; as highlighted in sections 3.0 and 4.0, contractor led design is an important factor for integration and front end strategic involvement. The hypothesis states that these factors should go some way toward providing a suitable platform on which to implement BIM technologies for the benefit of the project as design led by the contractor should facilitate more integration between design and contracting teams.

Ideally more projects would have been assessed but time constraints and a lack of suitable projects are a factor; it should be noted that it is particularly difficult to find a domestic main contractor making use of BIM technologies on a large scale.

5.5 Sampling; People

Equivalent actors where interviewed each time to allow more meaningful comparison and to achieve a rounded set of opinions for each project. Interviewees consisted of;

- The overall construction project leader
- A senior consultant from the design team (in all cases a manager from a structural design consultant*)
- A senior manager from the supply chain (in all cases a manager from a Mechanical and Electrical Services subcontractor*)

*Both disciplines of design and subcontract organisation are heavily involved with 3D modelling and BIM research.

Chapter 6: Findings and Discussion

This chapter will discuss the findings from the 9 semi-structured interviews carried out across 3 major UK projects.

6.1 Project Overviews

The following sections give an overview of each sample project.

6.1.1 Project A

Project A was a Design and Build project with novation. All respondents agreed that there was no project level strategy set for implementing BIM. However, managers from the design and sub-contract organisations stated that they had their own BIM implementation plans from the beginning of the project to deal with their own internal processes. The main contractor only attempted to implement BIM processes into the project once on site. Two respondents stated that the information management approach on this project could be described as 'standard' while one stated that they felt it was 'below standard'. Benefits attributed to BIM include;

- Pre-planning of the frame/site logistics in a BIM environment produced sequence models for key areas of the build which aided collaboration and communication
- The project is extremely spatially complex and services would not have been able to be coordinated without 3D (Subcontractor A)

6.1.2 Project B

Project B was a PFI project where the contractor was involved during the business case creation. All respondents agreed very strongly that there was a clear strategy for BIM implementation and that it was intimately linked to the project execution strategy from a very early stage. Respondent's where unanimous in describing the information management approach as 'innovative'. Benefits attributed to BIM include;

- Reduced setting out time dramatically and avoided errors
- 8 weeks ahead of programme on fit out
- £millions worth of inefficient clashes saved in design development
- Client understanding was a fundamental benefit as BIM assisted customer engagement
- Increased site engineers productivity to the point where managers are concerned that using them on a 'traditionally managed' project will render them ineffective

6.1.3 Project C

Project C was also a PFI project involving the contractor in development of the business case. Respondents agreed that the client was told the coalition would be using BIM. However no implementation strategy was put in place by the main contractor. Instead, staff from the main contracting organisations 'BIM research and development' team where drafted in to assist the project in implementing BIM later on. Respondents did not agree a description of the information management approach, which ranged from standard to innovative. Benefits attributed to BIM included;

- Coordination of design
- Collaboration sessions
- Logistics sequencing and communication

The following analysis sections correspond to the sections within the questionnaire (found in Appendix B) which was used as the framework for semi-structured interviews.

6.2 BIM and Information Management

The sample projects where selected based upon their utilisation of BIM technologies. The research sought to establish the extent of the BIM implementation strategy formulated by the project coalition. As discussed above, the strategies varied from Project B's prescriptive and proactive approach to Project A's lack of overriding strategy.

To measure awareness of BIM activity amongst coalition members, respondents where asked to complete a matrix containing some of the major packages of work generic to all projects, against a perception of BIM activity. The results can be found in Appendix D, which visually indicates the individual actor's perceptions of BIM activities for each project. Project B's respondents where unanimous in their opinion on what the other firms in the project where doing, showing a high level of adoption and integration. Project A was at the other extreme, in that all actors gave widely varying descriptions. The project leader for Project A observed that use of BIM amongst firms within the project coalition is patchy;

"It's a very disjointed picture. Companies that are using it are using it because it gives a distinct advantage to they work." (Project Leader A)

Answers from Project C also varied, but a pattern emerged showing that those in the design team where using a 'project specific' toolset, showing that the strategy for BIM and collaborative working seem to be specific to the design team and there was shared understanding and adoption. The results show that there is more shared adoption of BIM where there is a central strategy, thus aiding integration. Appendix E shows the results for questions 4, which measured actor's awareness of the types of technology being used, in a similar way to questions 3. Results where similar, with Project A's answers being the most differentiated and Project B's the most similar. Interestingly all projects had a unanimous take up of online collaboration tools, as this is a company standard and company wide implementation plans are in place which must be followed. BIM did not have the same levels of planning and support Projects A and C. Indeed, respondents revealed that there is much more confidence for team understanding of BIM where there is a defined strategy from the outset, as shown in Figure 6.0;

Average scores per project for Question 5; To what extent do you feel confident that others understand the objectives of BIM and act to achieve them?

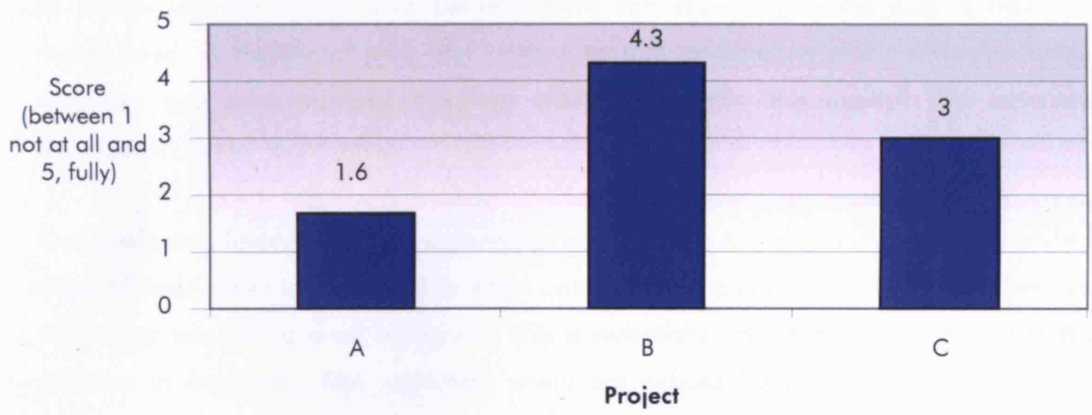


Fig 6.0; Bar chart showing answers for Q5

Project Leader B stated that since BIM tools where used as a collaborative platform for the whole project team, increasing understanding was a key part of his strategy;

"Everyone needs to understand the consequence of their information upon others – the hard tangible consequences of not collaborating properly" (Project Leader B)

This required constantly redelivering the message and re-focusing the team. Designer C also stated the importance of spreading the message.

Results also showed that where there was a set strategy and prescriptive protocols in place, there was a greater extent of buy in to the systems, as shown in figure 6.1.

Average scores per project for Question 6; To what extent do you believe BIM approaches have been embraced by the team as a whole?

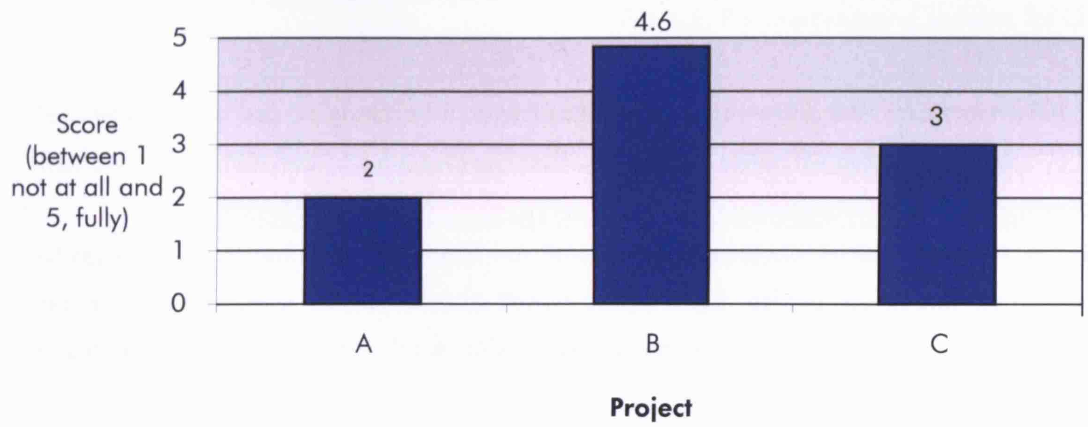


Fig 6.1; Bar chart showing answers for Q6

Even without a strategy, respondents still felt that using BIM had been positive and value had been added to individual firms. Project A showed the most differentiated use of BIM as there was no strategy with which to deal with integration between data sets. However, information could still be exchanged, aiding collaboration, by virtue of the software used. This requires trust as exchanging live design data between firms can incur risk as the data is able to be manipulated. A degree of trust was evident as BIM information was exchanged between designers and subcontractors; therefore providing benefits and positive BIM experiences described in further questioning.

One interesting finding was that respondents from Projects A and C both noted that whilst the effect of other actors in the project coalition using BIM had a positive effect on their firms work, the impact was not as great as desired. This is potentially attributable to the lack of strategic overview in implanting BIM; objectives where not defined from the outset and so benefits derived are in line with generic system functionality and are realised ad hoc.

8 out of 9 respondents felt that BIM had a positive or extremely positive effect on their tasks, as shown in Figure 6.2;

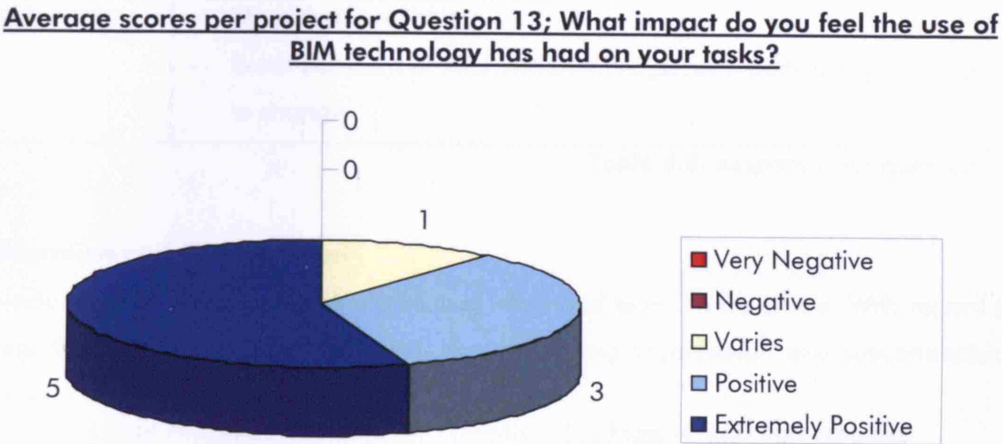


Fig 6.2; Pie chart showing answers for Q13

Even where there was no prescriptive project wide strategy governing BIM, respondents felt that their own use of BIM had had a positive impact upon others within the project coalition.

All respondents stated that they would use BIM on future projects; Project Leader A stated a desire to take it further on next project. Project Leader B echoed this noting that the next step would be to move to 5D technologies (please see Appendix A).

When asked what could further improve ways of working with regard to BIM, respondents had numerous ideas; however there were some recurring themes. The responses which correlate between peers are shown in Table6.0;

Group	Suggestions
Contractors Project Leaders	– More data available in BIM format (more firms in the project process to model) – Earlier involvement of contractor – Better information management across the project – Appropriate training, both technically and in terms of cultural approach
Designers	– More data available in BIM format (more firms in the project process to model and more modelling of building objects) – Earlier involvement of everyone; strategy set earlier – Better information management across the project – Appropriate training, both technically and in terms of cultural approach
Subcontractors	– More data available – Better standard of information management, particularly with regard to change

Table 6.0: Responses for question 18

6.3 Integration and Collaboration

All projects reported an open, collaborative and integrated team on the whole. With regard to the integration of tasks between designers, the contracting organisation and subcontractors, the following results where returned;

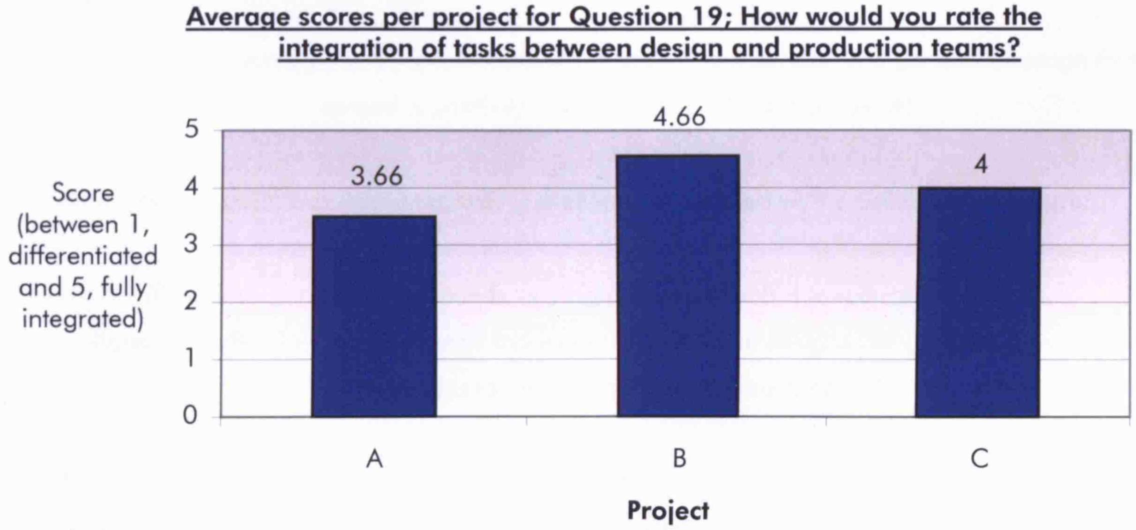


Fig 6.3; Bar chart showing answers for Q19

Project B (which contained the most prescriptive and detailed information management strategy) was perceived as having the highest levels of integration (closely followed by Project C). This may be due to the nature of PFI procurement; early involvement is required and there is generally more power, influence and centrality afforded to the contractor to enable strategic involvement. This is in part replicated by a D&B route but the involvement is much later, therefore strategic responsibility reduced.

All projects reported constant contact with other firms within the project coalition and stated that regular review meetings where held. One respondent stated that the only way to improve the situation would be to collocate.

In response to question 22, regarding the ability of the design team to access specialist subcontractors and suppliers (a measure of collaboration and integration), the general picture across projects was that access was readily available. One Project Leader stated;

"Designers best friends are specialists. If an architect wants to cut a piece of stone cut a specific way, don't talk to us (the main contractor). They have full access to the subcontractors and suppliers." (Project Leader A)

All projects where perceived to have a spirit of collaboration more akin to a 'One Team Approach' than traditional, adversarial approaches. This was also reflected in answers regarding how well the team worked together to resolve project issues. One respondent observed that collaboration was good but there are still contractual and commercial aspects causing tension, suggesting that these matters can be a hindrance to collaboration. Several respondents noted that there are still some individuals who act in a 'traditional' way but it is only a matter of time before their attitudes are changed. Project Leader A observed that;

"There are still some people's behaviours which aren't appropriate. The general message that is spread is positivity – let's do this!" (Project Leader A)

An interesting point was raised regarding problems associated with a collaborative culture;

"With hindsight the project needs very rigid change control to reduce wasted effort; collaborative decision making needs more control – multiple designs being made at the same time adds to complexity." (Subcontractor A)

This statement supports Barlow's supposition that too many interfaces can increase time spent communicating and therefore create inefficiencies within partnering and collaboration (Barlow, 1997).

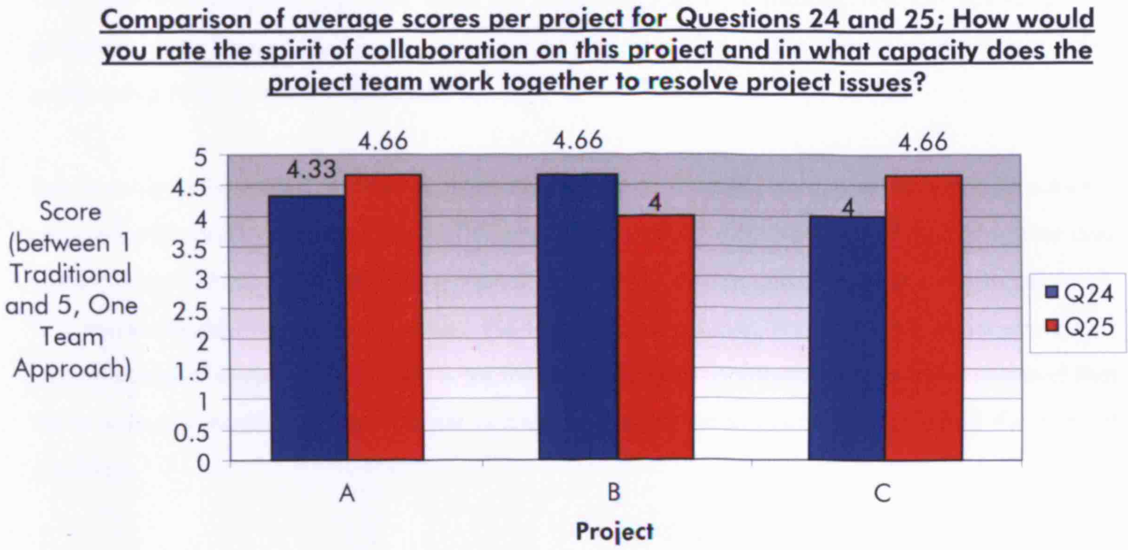


Fig 6.4; Bar chart comparing answers for Q24 and Q25

Interestingly, all projects had made minor organisational concessions regarding BIM. In each case the contractor had employed an individual to work with BIM systems. In the case of projects A and B this failed. The training and protocols in place provided a strict enough framework to sustain activity within the project coalition once this individual had moved on from project B. This was not the case with Project A. Project C continues to gain support from external individual within the contracting organisation to support BIM activities.

The activities which where carried out by the actors can be said to be a reflection of the quality of BIM strategy and the integration it achieved within the supply chain. Project Bs strategy and implementation plan was robust and prescriptive enough to integrate data sets and maintain momentum through the life of the project. Project C only came to a similar solution later in the project but on a less grand scale; in effect only encompassing designers. Project A did not achieve this; ongoing BIM activity is due to individual firms within the coalition using the technology for their own ends in a differentiated manner.

6.5 Relationships and Culture

When questioned about the openness of relationships between the constituent firms within the project coalition, all projects where described as 'Open' or 'Transparent'. Despite Project B being perceived as the most integrated and collaborative environment, the Project Leader stated that;

"I can only describe the relationships as open and not transparent as there is still the issue of a commercial aspect in all relationships." (Project Leader B)

This statement supports Cox and Ireland's assertion that truly mutual, win-win scenarios are paradoxical as leverage is always enjoyed by one firm due to the nature of the buyer-seller relationship (Cox and Ireland, 2006).

Relationships where also described as positive (8 out of 9 respondents), enthusiastic (8 out of 9 respondents), and pragmatic (8 out of 9 respondents). It is worth noting that the contractor and subcontractor where in partnering relationships with the design consultants at a corporate level. It is therefore assumed that this aided the factors listed above. However, the questions asked where intended to derive descriptions for the entire project coalition; no respondents stated that there was a distinction between firms outside of the partnering relationship within the project coalition.

Therefore it is assumed that the project leadership had a large influence on the individual project cultures. Each project leader stated that managing the project culture was important, one respondent stated that;

"Relationships and culture are a function of who is on the project at both a firm level and an individual level. Adversarial cultural issues sometimes persist although there are very few individuals like this and it is usually a matter of time before they are converted" (Subcontractor A)

Project Leader B identified that success relied upon human interactions and human understanding of both the technology available and how to provide leadership. Attitudes where stated as a priority for management focus;

"Anything is possible when you get the people sorted – it's all about leadership and example. You need to change behaviours and mindsets." (Project Leader B)

This is highlighted as a key factor in Morris's management of projects model;

"Unless attitudes are supportive and positive, the chances of success are substantially diminished" (Morris, 1994:241)

6.5 Further Discussion

Project Leader B recognized the tools as offering not only efficiencies in working for individual project actors, but also efficiencies in the process. By effectively preaching the process which was devised specifically for the project (including tools, protocols and desired outputs at key milestones) the Project Leader effectively embarked upon what Goffman calls a 'ritual of integration' (Goffman, cited in Cova and Salle, 2006). This ritual would be repeated as often as needed to ensure cooperation;

> "Strategies and culture help guide the context in which systems operate, guiding the thinking and behaviour of individuals in order that relations through individuals and systems are aligned." (Pryke, 2009:7 Forthcoming)

Project C also endeavoured to change behaviours but without a prescriptive strategy to begin with this was found to be more difficult. The importance of culture was also identified in Project A; the message spread was one of positivity and collaboration. However, there was little evidence to suggest that BIM featured in project 'rituals'.

Another interesting point to come out of the research was that Designer A believed that enabling a project for BIM is potentially a service proposition going forward because of the complexity and scale of the challenge. The role of the client was recognised as important for adoption for BIM enabled projects as ultimately it is they who need to influence the supply chain and possibly pay for its development.

Also, all respondents stated that the most difficult party to convince with regard to adopting an integrated BIM approach was the lead architect. All sample projects featured large, prestigious architectural practices. In the case of Project A, the architects power and influence was most notable and it was inferred that it actually undermined the approach of the contracting organisation despite the contractor's responsibility for both design and production. Again the role of the client was highlighted as a factor;

> "My message is that there is a definite benefit (regarding BIM), but this is restricted. We can only take it so far because unless you have other members of the team in the same place as you and as enthusiastic, it becomes very hard to get designers to do things they don't normally do. The Client-Architect relationship is important. The client's role is a key factor; they almost need to think with a manufacturing mindset to get Designers to begin working in this way," (Project Leader A)

Chapter 7: Conclusions and Recommendations

7.1 Introduction

This chapter will draw conclusions from the primary research findings discussed in the previous chapter. Recommendations will also be made for practical application of the lessons learned and ideas for further research put forward.

The research question posed by this report was one of structural barriers prohibiting the implementation of integrated information management systems by main contractors on UK construction projects. The literature review found procurement routes to be a primary factor. Secondly, other related factors such as power, culture and relationships where found to further prohibit implementation, but it was suggested that these where part of the same structural problem.

This report suggested that a more appropriate environment for the utilisation of BIM technologies would be one of integral working. It was expected that more successful BIM implementations would be observed where the main contractor enjoyed early involvement, a high degree of integration between design and production teams and a high level of influence over both delivery strategy and the constituent firms within the coalition, provided by strategic input. It was also noted that a significant factor within this environment would be soft issues such as attitudes, behaviour and culture. The expectation was that the two PFI schemes sampled would yield the greater degree of BIM implementation, providing;

- More project successes attributed to the use of integrated BIM systems
- Greater understanding of BIM amongst coalition members
- Higher uptake amongst coalition
- Greater awareness of usage by other firms within coalition
- Greater understanding of the benefits, practices and tools
- Full ownership of the BIM environment by the contractor

The following sections will make conclusions and where appropriate recommendations, regarding each of the suggestions for successful BIM implementation, put forth by this report.

7.2 Conclusions on Early Involvement

From the research it is clear that early involvement for the contractor provides the opportunity to innovate when developing an information management strategy. This supports the proposition that procurement route is a major influence on the structural barriers imposed on a contractors information management process, and therefore BIM.

However, the research suggests that developing a robust strategy, which is implemented early and has the buy in of all actors, was paramount. It was clearly evident from the sample projects that attempting to implement a BIM system well into the project lifecycle reduces benefit and inhibits utilisation.

7.3 Conclusions on Integration

BIM was found to be more successful where there was a higher degree of integration perceived within the project coalition; the PFI projects. Again, this supports the core proposition that procurement routes are a predominant structural influence on a contractor's information management process.

This report suggested that traditionally procured projects may not provide the level of integration required to benefit from project level BIM systems. A lack of sample projects means that this can neither be completely proved nor disproved within this study, but the success of the PFI projects is encouraging. However, as evident in the Design and Build project, individual firms can still harness aspects of the various BIM technologies to improve their internal processes.

It is difficult to conclude as to whether BIM assisted in integrating the team or whether the integration of the team assisted in the uptake of BIM; it could be argued that both are true. The findings suggest that the integrative capacity of technology can assist in integrating actor work streams (questions 13-15). There are few, if any systems which service the information generation and processing requirements of the whole project coalition; therefore some level of interoperability will be required between disparate systems. The higher the level of integration between software's, the more integration can be achieved at a task level between project actors.

It is recommended that contractors seeking to implement a project level BIM system should focus on;

- Selecting projects where the procurement route offers high levels of integration and/or;
- Utilising SCM techniques to integrate design and production teams, facilitating mutual development and knowledge sharing (to be explored in section 7.5).

7.4 Conclusions on Strategic Input

Strategic involvement can be separated into two closely related issues within the framework presented. These are;

1. The strategic involvement required in structuring the project organisation to create the optimum information flows

2. The capacity to create a structured, project level information management strategy

It can be concluded that BIM implementation is more successful where the contractor enjoys strategic responsibility for more of the project lifecycle, not just responsibility for production and design. PFI routes allowed the contractor more strategic input which, in the most successful BIM implementation, was used to influence the project process, including the information management approach.

As with integration, the contractor does not select the procurement route, therefore strategic responsibilities may be restricted. However, the formation of partnering relationships with clients may help provide this.

It is also recommended that the project manager takes a strategic view of the BIM systems and protocols used as they are crucial to creating integrated information flows; this may be different for every project due to unique technical demands.

7.5 Conclusions on Partnering/SCM

All sample projects contained partnering relationships between designers and the main contractor. BIM implementation was found to be more successful when there was effort put into consensus building regarding systems, tools and protocols and mutual knowledge sharing. It can be concluded that moving to an SCM focus, where supplier development and integration between teams is a primary concern, provides further opportunities for successful implementation. However, a partnering relationship is the first step and clearly provided cultural benefits.

SCM relies upon the main contractor to establish long term relationships with subcontractors and suppliers. Since BIM systems rely upon design data, it is suggested that a contractor adopts SCM relationships with designers also. Designer and supplier development regarding BIM opens opportunities such as using shared product libraries, automated design costing and computer aided manufacture etc. In the interim, knowledge sharing, clustering around BIM, methodology development and estimating using BIM technologies should be explored.

7.6 Conclusions on Leadership and Culture

All projects reported collaborative cultures but both BIM successes and failures occurred; it cannot be concluded that collaborative culture alone provides the correct setting for integrated BIM. Culture is an important factor; there is clearly a requirement for positivity and openness within relationships when introducing a programme of change and a notable element within the observed relationships was the element of trust.

Also, where creation and communication of the desired cultural values and approach where given extensive attention by the project leadership, the results of BIM implementation where more encouraging.

Indeed, during the field research the importance of leadership repeatedly emerged as a key factor. The following factors, attributed to proactive leadership, where clearly evident where BIM implementation had been a success;

- BIM focused 'rituals of integration' to provide the right attitudes across the team
- Creating buy in and consensus building amongst coalition members (themes of political manoeuvring and trust are present)
- Continuous communication and reinforcement of the message
- Knowledge exchange

Transparency between firms seemed elusive due to commercial pressures. It is difficult to conclude what this means for implementing technologies such as 5D (please see Appendix A for a description), where costing information is inherent within the BIM system; this requires further exploration.

It is recommended that the project leadership needs a firm understanding of their objectives, the technology and of how to lead change in a complex environment.

7.7 Conclusions on Power and Influence

Power and influence where derived from the imposed procurement routes. The power of appointment did not feature heavily as the consultants where novated on each scheme. However, the partnering relationships identified did seem to replicate some of this power as there is an expectation of working together in the future; maintaining positive relationships is important for securing further work. It can be argued that this contributed to the collaborative cultures evident on all projects.

Influencing the consultants to practice BIM methodologies in line with a project strategy was only evident on the PFI projects (although this may have been helped by the fact that the designers and subcontractors interviewed where looking to implement BIM internally). BIM was more successful where the main contractor took control of the implementation, driving standards and protocols. It can be concluded that design responsibly alone is not enough to ensure successful implementation a BIM system at project level.

There is clearly a requirement for a powerful central actor to lead creation of an information management strategy. It is suggested that influence should be used to create a consensus and direct strategy building but this should be done collaboratively, utilising knowledge sharing, supporting integral working and therefore non adversarial environments.

The power of appointment may be used by a contractor to procure the services of firms who are willing to work in an integrated BIM environment; linking back to the arguments made in section 7.5.

7.8 Recommendations for further research

Many interesting points where discovered during the course of this research which where unfortunately unable to be explored in more depth. The following ideas are raised as possible avenues for further research to deepen understanding of the role of BIM within 21st Century project delivery;

- Map the information flows, using Social Network Analysis, on a BIM enabled test project to highlight issues such as dominance and centrality, which could be used to further understanding regarding how the information flows behave in relation to the project management approach;
- More extensive analysis of live projects would be useful, requiring observation of the total project lifecycle and mapping out the systems and protocols used;
- The inclusion of traditionally procured projects without partnering may cast further light upon integrative problems and BIM;
- Observation of a BIM enabled cluster; comparison of the benefits of using a concurrent design, pricing and programming system (5D) by an integrated design and production team against a non BIM enabled cluster.
- Further discussion is called for regarding integrated BIM use as a potential core competency designed to give competitive advantage (Hamel and Prahalad, 1994).

7.9 Concluding Remarks

In essence this research is about the difficulties in adopting new, integrated approaches to project management in a contracting organization, with context given in the form of Building Information Modelling and the writer's observations on the lack of synergy between BIM and today's generic project approaches.

This report suggested that BIM, as a project management information system, can be useful to the project coalition, especially given the integrative focus of improvement literature. It was highlighted however, that main contracting organisations have been slow to integrate the technology into their business processes. Through research, this paper hypothesised that the fragmentation inherent within traditional procurement systems inhibit the integrative capacity of BIM, and that the contractor is denied the power, influence and strategic capacity to apply a structured, technologically advanced information management strategy.

The findings of this research support the view that 21st Century project approaches can provide a more hospitable environment for BIM by providing the contractor with earlier involvement, more power over the supply chain, more strategic responsibility, collaborative culture and integration between the design and production functions. However, the research highlighted that there are a host of other issues which can affect success and that should be carefully considered, including;

- The level and scope of strategic involvement of the main contractor and how this is leveraged to shape information flows
- The need for more in depth, strategic relationships between parties (SCM techniques)
- A technologically informed leadership with an understanding of cultural change

Finally, this research has shown that a strategic view is vital to utilising innovative, integrative tools such as BIM; this requires consideration from not only the contractor, supply chain and design partners, but also from client organisations as it is they who procure projects.

References

Aouad, G., Ormerod, M., Sun, M., Sarshar, P., Barrett, Alshawi M. (2000) *Visualisation Of Construction Information: A Process View,* International Journal of Computer-integrated Design and Construction, 2(4), 206-214

Barret, P. and Stanley, C. (1999) *Better Construction Briefing,* Oxford: Blackwell Publishing

Barlow, J., Cohen, M., Jashpara, A. and Simpson, Y. (1997) *Towards Positive Partnering,* Bristol: The Policy Press.

Boyle, G., (2003) *Design Project Management;* Aldershot: Ashgate

Cain, C. T., (2003) *Building Down Barriers: A Guide to Construction Best Practice,* London: Spon Press

Cartlidge, D. (2004) *The Procurement of Built Assets,* Oxford: Elsevier Butterworth-Heinemann

Checkland, P., and Scholes, J. (1990) *Soft Systems Methodology In Action,* Chichester: Wiley

Cova, B. and Salle, R. (2006) "Communications and Stakeholers", in Pryke, S.D. and Smyth, H.J. (ed.), The Management of Complex Projects, Oxford: Blackwell Publishing.

Cox, A., Ireland, P. and Townsend, M. (2006) *Managing in Construction Supply Chain and Markets,* London: Thomas Telford

Daniel, D.W. (1990) Hard problems in a soft world, International Journal of Project Management, *8,* 79-83.

Egan, Sir J. (1998) *Rethinking Construction*, London: DETR.

Emmit, S. (2007) *Design Management for Architects*, Oxford: Blackwell Publishing

Franks, J. (1998) *Building Procurement Systems; A Clients Guide,* 3rd Ed, Harlow: Longman

Hamel, G., and Prahalad, C. K. (1994) *Competing For The Future,* Boston: Harvard Business School Press

Handy, C. (1999) *Understanding Organizations,* 4th Edn, London: Penguin Group.

Holti, R., Nicolini, D. and Smalley, M. (2000) *Building Down Barriers: The handbook of supply chain management - The Essentials*, London: CIRIA.

Latham, M. (1994) *Constructing the Team: Joint Review of Procurement and Contractual Arrangements in the UK Construction Industry,* London: HMSO.

Lee, A., Wu, S., Marshall-Ponting, A., Aouad, G., Cooper, R., Tah, J. H. M., Abbott, C. & Barrett, P. S. (2005) *nD Modelling Roadmap: A Vision for nD-Enabled Construction,* Salford: University of Salford

Morris, W. G. P. (1994) *The Management of Projects*, London: Thomas Telford
National Audit Office (2001) *Modernising Construction: Report By The Comptroller and Auditor General,* London: National Audit Office

Pryke, S.D. (2004) *Twenty-First Century Procurement Strategies: Analysing Networks of Inter-Firm Relationships*, London: Rics Foundation

Pryke, S.D. (2005) *Supply Chain Management in Construction : Origins, concepts and ideals,* Internal Paper, London: UCL.

Pryke, S.D. [Ed.] (2009) *UK Construction Supply Chain Management: Concepts and Practice,* Oxford, Wiley - Blackwell (currently in production)

Venkataraman, R. (2004) *Project Supply Chain Management: Optimizing Value: The Way We Manage The Total Supply Chain*, in Morris, P.W.G. & Pinto, J.K. (Eds.), *The Wiley Guide to Managing Projects*, New Jersey: John Wiley & Sons

Walker,A. (2002) *Project Management in Construction,* 4th Ed, Oxford: Blackwell

Winch, G. M. (1998) *Zephyrs of creative destruction: understanding the management of innovation in construction,* Building Research & Information, 26(4), 268–279

Winch, G. M. (2002) *Managing Construction Projects; An information processing approach,* Oxford: Blackwell

Womack, J., Jones, D., and Roos, D. (1990) The Machine that Changed the World, *London: Simon & Schuster.*

Internet Sources

Staub-French, S., and Khanzode, A., (2007) *3D and 4D Modeling For Design and Construction Coordination: Issues and Lessons Learned,* ITcon Vol. 12, pg. 381-407, http://www.itcon.org/2007/26 (accessed 01/09/08)

http://www.agc.org/cs/news_media/press_room/press_release?pressrelease.id=192, (accessed 07/07/2008)

http://www.navisworks.com/index.php?q=solutions/casestudies/baa, accessed (21/06/2008)

Appendix A: Building Information Modelling Discourse

The following discussion is provided as background reference to many of the terms and concepts discussed in the main research report.

1.0 Information Generation

Currently, a contracting organization's processes are driven initially by the design of the product. Design information drives measurement, pricing and programming which are completed as separate 'silos' of activity. The information input is the same (design) but the outputs are different; Bills Of Quantities, Cost Plans, Detailed Cost Estimates, Programmes and even further design such as reinforcement detailing. At present few, if any, of these are automated outputs from design information in UK projects; the information is interpreted by skilled actors and the output created using recognized methodologies, some being industry standards (SMM7 for measurement) and some purely experience based (programme logic for a Gannt Chart).

A large part of construction management is the reinterpretation and eventual output of new information as the design evolves during the lifecycle of the project. In effect this requires constant monitoring and adaptation of outputs, as appropriate. The result is that the project management team is forced to spend a large proportion of time responding to changes rather than proactively controlling the project.

Where a contactor leads the design they will be integrated further into the design process and therefore be able to give feedback on design options. Yet even on 'early contractor involvement schemes' a contracting organization still relies on its recognised processes and 'hard' systems; old 'over the wall' style of exchanging design information and hiving output into data silo's is still very much in place despite control of design activities.

Construction orientated innovations, going beyond 3D Computer Aided Design, have started to emerge onto the open market. In many design led industries, CAD is no longer simply about representing design information but about creating design content, amendment, testing and ultimately fabrication. 3D modelling techniques have provided reduced design cycle times by allowing integrated design of product components, brought together and coordinated in a single environment by different teams, even in different locations (using internet technology). These technologies have started to go further, allowing users to derive 'intelligence' from models. Finite element analysis in the 3D environment is a technology which has found its way into construction, but manufacturing industries have long used intelligent 3D models to create Bills of Materials, costing information and even allow tracking through the manufacturing process, using the same data sets.

One of the core underlying principles of emerging BIM technologies is that a 3D model can generate output accurate data based upon its geometry; it can be 'intelligent'. By linking outputs from these technologies to 'hard' management tools, such as Gannt and Estimating databases, accurate data can be automatically leveraged for decision making in other disciplines. Further more, when design geometry is updated the output data is again sent through the system, thus introducing a reciprocal information flow into a process which was previously fragmented and the quality of which was based upon a skilled actor's interpretation (therefore allowing the inclusion of transposition errors).

Software providers are beginning to offer tools which attack the front end of a project (from the contractors view point) by allowing not only scheduling of activates, costing and other information generation and manipulation, all in a 3D environment An emergent strategy of software firms seems to be the reproduction of 'hard' system approaches, but with the twist of being integrated into a suite of tools where outputs are driven by 3D design, as discussed in the previous section. These new tools will now be outlined briefly.

2.0 Tool Outlines

This section aims to give brief overviews of some of the items mentioned in the main report. Since many of the following terms are relatively ambiguous and require definitive definition, they are presented as a guide only to the technologies currently under development or on the market.

3D modelling technologies are now relatively common place amongst design professionals and need no introduction. 3D visualisation is used routinely amongst architects; 3D drafting and Finite Element Analysis are commonly used by both Structural Engineers and Mechanical and Electrical service engineers respectively to design 3 dimensional object models of their product. These CAD platforms allow a level of collaboration by providing the facility to import data from numerous sources and integrate it into a single model of the product; a digital prototype. However, we can now go further with 3D environments and generate or link to other 'resources' over and above designed objects.

As Winch (2002) states, it is now possible to visualise the project programme in a 3D computer environment. Termed 4D, these tools are effectively 3D models with the addition of time resources. The more sophisticated of these systems use programmes developed by planning staff and link tasks to objects in 3D space, thereby allowing a visualization of the construction programme. Taking this concept further, some systems allow the programme to be manipulated inside the 4D software, thus altering the visualization and allowing testing of scenarios. Also good for communication of issues, briefing, spatial and logistical planning.

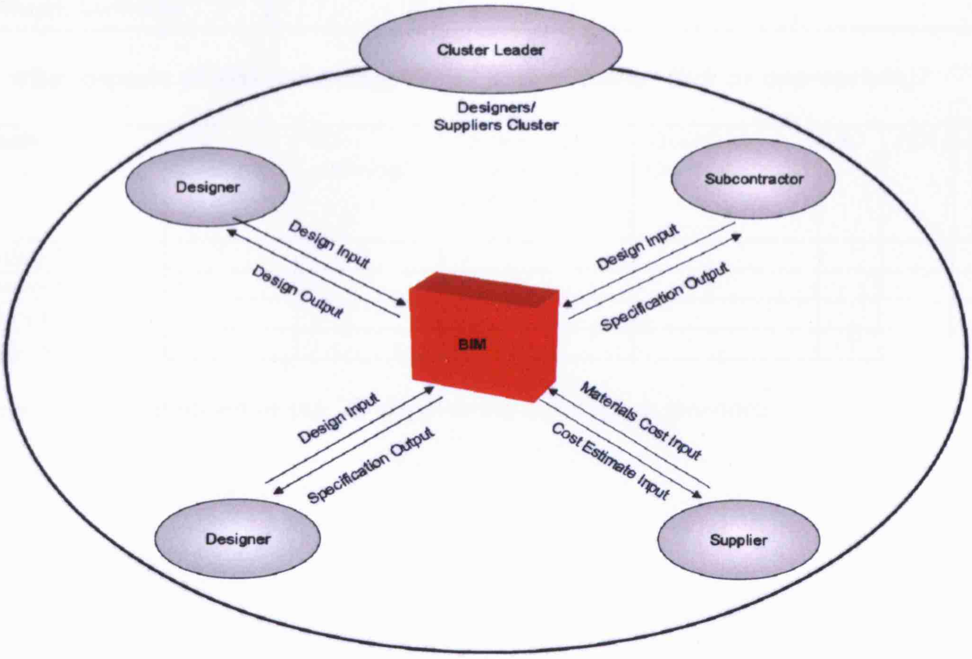
5D is commonly termed as the linking of costing to a 4D environment. 3D objects generate quantities of materials or component parts, which can have lump cost items or rates applied. This in effect allows the cost estimation of 3D prototypes. For example; a structural design amendment such as a column thickness change, done in 3D space, can drive new quantities output, which in turn is intimately linked to an estimating database, thus altering the estimated price of the column. In a similar way the data can drive an increase in formwork allowance, or in the programme increase gang time needed to erect the formwork, altering the work rate allowance and logic of a programme. Also, estimating information may be fed to a project budget within the system, calling into force tools such as Earned Value Analysis.

nD is a term which is being used to further debate around BIM. Effectively, nD is anything you care to think of beyond established paradigms such as 4D;

> "nD modelling develops the concept of 4D modelling and aims to integrate an nth number of design dimensions into a holistic model which would enable users to portray and visually project the building design over its complete lifecycle." (Lee et al 2005:17)

Another aspect of building information modelling is the documentation element. Some systems offer digital repositories for documents; drawings, specifications, Health and Safety files etc. Using a 3D model as the user interface, the documents can be 'attached;' digitally to its geometric representations. Thus, if a Facilities Manager needs to order a new ceiling panel, he or she can access the BIM and navigate to the appropriate component and retrieve all the information about it from its associated repository. This technology is not a far cry from the digital 'collaboration' tools on the market.

3.0 Concept Model for Clustering System



Appendix B: Research Questionnaire

Respondents were asked to expand upon any point which they feel it appropriate

Section 1: BIM and Information Management

1. ***Is there a project level BIM strategy and toolset (are the resource bases making used of each others data through and integrated system)?***

YES/NO

2. ***At what point was your BIM strategy set?***

3. ***To what level are constituent firms within the project coalition using BIM on the project (tick box as appropriate)?***

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch					
Detail Arch					
Structural Engineer					
M&E Consultant					
M&E installer					
Cladding Manufacturer					
Formwork Designer/Supplier					
Concrete Frame Subcontractor					
Steelwork Contractor					

4. ***What aspects of BIM technology is the project using* (tick as appropriate)?***

Team	3D Drafting	4D planning	Online Collaboration software	Quantities Generation	5D	FEA	3D Coord /Clash detection
Design Team							
Contractor							
Subcontractors							
Suppliers							

*It is assumed that all teams use 2D engineering drawings as standard

5. ***To what extent do you feel confident that others understand the objectives of BIM and act to achieve them (circle as appropriate)?***

Not at all 1 2 3 4 5 Fully

6. ***To what extent do you believe BIM approaches have been embraced by the team as a whole (circle as appropriate)?***

Not at all 1 2 3 4 5 Fully

7. ***Who is responsible for BIM strategy and implementation?***

	Strategy	Implementation
Everyone (Collaborative)		
Everyone (Differentiated)		
Design Team		
Production Teams		

8. ***Who is responsible for training standards and protocols?***

____

9. ***Was BIM competency a consideration in appointments for the project?***

YES/NO ______________________________

10. ***Did a BIM methodology feature in the initial project execution strategy?***

YES/NO ______________________________

3.b) If so, who developed this strategy?

____

11. ***How would you describe the IM approach on this project (circle as appropriate)?***

Below standard Standard Varies Innovative Very Innovative

12. Who do you believe is best placed to model the project (including design objects, logistics objects, site layout etc?

13. What impact do you feel the use of BIM technology has had on your tasks (circle as appropriate)?

a) Very negative Negative Varies Positive Very positive

b) Costly Break even Hard to say Some value added Lots of Value added

14. Do you feel that your use of BIM has had a positive impact upon other team members?

YES/NO

15. Do you feel that other team member's use of BIM has had a positive impact upon you?

YES/NO

16. Would you adopt this way of working on another project?

YES/NO

17. Are there any particular instances of success which you attribute to the use of BIM on the project?

Notes:

18. What do you feel could further improve the way of working with regard to BIM?

Notes:

Section 2: Integration and Collaboration

19. How would you rate the integration of tasks between design and production teams; do the teams collaborate around major tasks (circle as appropriate)?

Differentiated 1 2 3 4 5 Fully Integrated

20. How often do you communicate with other firms within the team by email/ phone/ face to face (circle as appropriate)?

Little as possible When required Varies Often Constantly

21. How often do the design and production teams meet to review the project (circle as appropriate)?

Never Rarely As required Often Regularly

22. Does the design team have access to the specialist subcontractors to enable collaborative design development?

YES/NO

23. How often would you say the design and production teams collaborate around specific problems (circle as appropriate)?

Never Rarely As required Mostly Always

24. How would you rate the spirit of collaboration on this project (circle as appropriate)?

Traditional 1 2 3 4 4 5 One team approach

25. In what capacity does the project team work together to resolve project issues (circle as appropriate)?

Traditional 1 2 3 4 4 5 One team approach

26. Have there been any changes in organisational structure to compensate for the particular challenges of the project strategy, particularly in relation to BIM?

Notes:

Section 3: Relationships and Culture

27. How would you describe the relationships between the design, contractor and specialist teams (circle as appropriate)?

a) Dishonest	Guarded	Varies	Open	Transparent
b) Very negative	Negative	Varies	Positive	Very positive
c) Very apathetic	Apathetic	Varies	Enthusiastic	Very enthusiastic
d) Thoroughly Idealistic	Idealistic	Varies	Pragmatic	Thoroughly Pragmatic

Notes:

28. How would you describe the project team's culture in relation to adopting new processes (circle as appropriate)?

a) Very reactive	Reactive	Varies	Proactive	Very proactive
b) Very negative	Negative	Varies	Positive	Very positive
c) Very apathetic	Apathetic	Varies	Enthusiastic	Very enthusiastic
d) Very Traditional	Traditional	Varies	Innovative	Very innovative

29. Tell me about your general experience on the project in comparison to other projects, including any specific scenarios / examples which you think are relevant.

Notes:

Appendix C - Project background information

PROJECT A	
Value of Works:	£480m
Procurement/Tender Route:	Design and Build with novation
Contract Used:	JCT 2005 With Contractors Design
Stage of involvement for main contractor:	Stage C/D
Length of construction programme:	220 weeks construction programme
Description of Project/Scope of Works: Detail design and construction	
The speculative development comprises of ultra high end luxury apartments with retail and leisure facilities. Above ground a series of 4 Pavilion's ranging between 10 and 14 stories encompassing high spec, high security apartments, retail units at street level. Below ground a 4 story basement encompassing retail delivery facilities, car park, leisure facilities and a link through to adjacent hotel. The structure comprises a reinforced concrete frame with pre-cast columns and a series of steel cores linking each pavilion. The fit out comprises of bespoke interior design with highly serviced area to cater for multiple living areas and uses.	

PROJECT B	
Value of Works:	£293m
Procurement/Tender Route:	PFI/PPP, fixed price lump sum. Totality of risk with consortium
Contract Used:	Standard Form, Scottish gov PFI
Stage of involvement for main contractor:	Pre-RIBA stages. Involved in business case before design briefings
Length of construction programme:	205 weeks construction programme
Description of Project/Scope of Works: Business Case, Concept Design, Detail design and construction	
PFI Hospital development including 95,000m2 building footprint on a 275,000m2 site. Ranging from 3-4 stories the development includes highly serviced wards comprising insitu and precast concrete and steel structure, feature stonework, a duel fuel generator and 1500 parking spaces in a parkland setting.	

PROJECT C	
Value of Works:	£231m
Procurement/Tender Route:	PFI/PPP, fixed price lump sum. Totality of risk with consortium
Contract Used:	Standard Form PFI
Stage of involvement for main contractor:	Pre-RIBA stages. Involved in business case before design briefings
Length of construction programme:	239 weeks construction programme
Description of Project/Scope of Works: Business Case, Concept Design, Detail design and construction	
PFI Hospital development including 65,000m2 building footprint. Ranging from 3-4 stories the development includes highly serviced wards comprising insitu and precast concrete and steel structure, feature stonework, a duel fuel generator and parking facilities. The hospital features unique single bed rooms.	

Appendix D; Question 3 Findings Comparison

Question 3 asked; *To what level are constituent firms within the project coalition using BIM on the project (tick box as appropriate)?*

Project A

Project Leader:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch			■		
Detail Arch			■		
Structural Engineer		■			
M&E Consultant	■				
M&E installer		■			
Cladding Manufacturer	■				
Formwork Designer/Supplier	■				
Concrete Frame Subcontractor		■			
Steelwork Contractor		■			

Subcontract Firm Manager:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch		■			
Detail Arch		■			
Structural Engineer		■			
M&E Consultant		■			
M&E installer		■			
Cladding Manufacturer					■
Formwork Designer/Supplier					■
Concrete Frame Subcontractor		■			
Steelwork Contractor		■			

Design Firm Manager:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch	■				
Detail Arch	■				
Structural Engineer		■			
M&E Consultant	■	■			
M&E installer		■			
Cladding Manufacturer					■
Formwork Designer/Supplier					■
Concrete Frame Subcontractor		■			
Steelwork Contractor					■

The findings from project A suggest a high level of differentiation in the understanding of project actors of what other project actors are doing regarding BIM. This shows that there is either no strategy or it has failed to be communicated,

Project B

Project Leader:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch					
Detail Arch					
Structural Engineer					
M&E Consultant					
M&E installer					
Cladding Manufacturer					
Formwork Designer/Supplier					
Concrete Frame Subcontractor					
Steelwork Contractor					

Subcontract Firm Manager:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch					
Detail Arch					
Structural Engineer					
M&E Consultant					
M&E installer					
Cladding Manufacturer					
Formwork Designer/Supplier					
Concrete Frame Subcontractor					
Steelwork Contractor					

Design Firm Manager:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch					
Detail Arch					
Structural Engineer					
M&E Consultant					
M&E installer					
Cladding Manufacturer					
Formwork Designer/Supplier					
Concrete Frame Subcontractor					
Steelwork Contractor					

The findings from Project B show a strong correlation between answers, suggesting a high degree of integration within the project team and a definitive strategy regarding BIM use.

Project C

Project Leader:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch				■	
Detail Arch				■	
Structural Engineer				■	
M&E Consultant	■				
M&E installer			■		
Cladding Manufacturer					■
Formwork Designer/Supplier		■			
Concrete Frame Subcontractor		■			
Steelwork Contractor	n/a				

Subcontract Firm Manager

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch			■		
Detail Arch				■	
Structural Engineer				■	
M&E Consultant		■			
M&E installer				■	
Cladding Manufacturer					■
Formwork Designer/Supplier					■
Concrete Frame Subcontractor		■			
Steelwork Contractor	n/a				

Design Firm Manager:

Project Coalition: Member Firm	Do nothing	Use own systems or protocols in isolation	Introduced to project systems and protocols but not using them	Using project systems and protocols	Don't Know
Lead Arch				■	
Detail Arch				■	
Structural Engineer				■	
M&E Consultant		■			
M&E installer		■			
Cladding Manufacturer	■				
Formwork Designer/Supplier	■				
Concrete Frame Subcontractor		■			
Steelwork Contractor	n/a				

The results from project C show some correlation, suggesting some level of understanding of what other actors are doing. This suggests there is some strategy governing the use of BIM.

Appendix E; Question 4 Findings Comparison

Question 4 asked; *What aspects of BIM technology is the project using (tick as appropriate)?*

Project A

Project Leader:

Team	3D Drafting	4D planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coord/Clash
Design Team	■		■				
Contractor		■	■				■
Subcontractors	■		■				
Suppliers			■				

Subcontract Firm Manager

Team	3D Drafting	4D planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coord/Clash
Design Team			■				
Contractor			■				
Subcontractors	■	■	■				■
Suppliers			■				

Design Firm Manager:

Team	3D Drafting	4D planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coord/Clash
Design Team	■		■			■	
Contractor	■	■	■				
Subcontractors			■				■
Suppliers			■	■			

The results show a lack of correlation regarding modelling technologies but a strong correlation for use of document management/collaboration software. This is due to the fact that the project coalition must use this software and a robust implementation plan is in place. This is not the case with modelling technology.

Project B

Project Leader:

Team	3D Drafting	4D Planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coordination/Clash Detection
Design Team							
Contractor							
Subcontractors							
Suppliers							

Subcontract Firm Manager

Team	3D Drafting	4D Planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coordination/Clash Detection
Design Team							
Contractor							
Subcontractors							
Suppliers							

Design Firm Manager:

Team	3D Drafting	4D Planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coordination/Clash Detection
Design Team							
Contractor							
Subcontractors							
Suppliers							

The responses show a high level of correlation showing that the team understands the technology being used by other members of the project coalition. This shows a strong degree of integration and the likelihood of a robust strategy.

Project C

Project Leader:

Team	3D Drafting	4D planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coord /Clash
Design Team	■		■				
Contractor		■	■				■
Subcontractors	■		■				
Suppliers			■				

Subcontract Firm Manager

Team	3D Drafting	4D planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coord /Clash
Design Team	■		■			■	
Contractor		■	■				■
Subcontractors	■		■				■
Suppliers			■				

Design Firm Manager:

Team	3D Drafting	4D planning	Online Collab software (A-site)	Quantities Generation	5D	FEA	3D Coord /Clash
Design Team	■		■			■	
Contractor	■	■	■				
Subcontractors			■				■
Suppliers			■	■			

The results show that there is some correlation between responses suggesting some level of strategy regarding BIM. The Online Collaboration Software scored the highest correlation as all actors on the project must use it and there is a robust implementation plan attributed to this tool.